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Departamento de Eletrónica,
Telecomunicações e Informática

Rodrigo Gouveia de Carvalho e Castro Dias

Métricas de Gestão de Desempenho em Tempo Real e Longo Termo em Redes Móveis

Real Time and Long Term Performance Management Metrics in Mobile Networks

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Real Time and Long Term Performance Management Metrics in Mobile Networks

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia Eletrónica e de Telecomunicações, realizada sob a orientação científica do Doutor Manuel de Oliveira Duarte, Professor Catedrático do Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro.

O Júri

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Palavras-chave

Tempo Real, Longo Prazo, Gestão, KPIs, Desempenho, Integração, Relatórios, Contadores, Comutação de Circuitos, Comutação de Pacotes, Redes Móveis

Resumo

A indústria das Telecomunicações é um mundo onde os serviços de dados, voz e outros serviços importantes têm que estar disponíveis sempre e em todo o lado. Por causa dessas exigências, tornou-se um mercado extremamente agressivo, onde o menor detalhe pode fazer a diferença. Um desses detalhes diferenciadores está relacionado com a gestão da rede. Com todas as mudanças e rápida evolução das telecomunicações, este pode ser considerado um ponto crítico. Uma gestão eficiente e otimizada pode poupar tempo e dinheiro e por isso é um aspeto crucial deste mercado. Em termos de gestão e monitorização das redes, há dois caminhos a considerar: gestão a longo prazo, que consiste em salvar dados menos detalhados por longos períodos de tempo; e gestão em tempo real, que permite dados muito mais detalhados mas durante uma janela temporal consideravelmente menor. Devido a limitações ao nível da base de dados e elevados custos, apenas um deve ser escolhido, o que leva a que se perca alguma informação em qualquer dos casos. Assim, podem surgir problemas cuja resolução será complicada e dispendiosa.

Posto isto, seria extremamente benéfico para as Operadoras de Telecomunicações, se pudessem analisar os dois tipos de dados, tendo a informação a longo prazo juntamente com os detalhes mais importantes em tempo real numa só aplicação.

Keywords

Real Time, Long Term, Management, KPIs, Performance, Integration, Reports, Counters, CS, PS, Mobile Networks

Abstract

The Telecommunications industry is a “world” where services like data, voice and value-added services must be available at anytime, anywhere. Because of this requirement, it became a really aggressive market, where the least detail can make the difference. One of the details that can be really differentiating is related to network management. With all the changes and rapid evolution of telecommunications, this can be considered a critically important point. An efficient and optimized network management can save time and money and that is why it is a mandatory aspect in this market. There are two different paths to be considered: long term management, which consists in saving less detailed data for long periods of time, and real time management that allows much more detailed information for narrower time frame. Because of database and costs related issues, only one of them must be chosen and there is some important information that may become “invisible”, leading to unsolved problems that can be highly expensive.

Regarding this situation, it would be extremely beneficial for the telecom operators if they could visualize both types of data, having the long term information along with the most important details of real time information in one view.

CONTENTS

List of Figures

List of Tables

List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
APN	Access Point Name
ATM	Asynchronous Transfer Mode
AuC	Authentication Centre
ARPU	Average Revenue Per User
BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CAPEX	Capital Expenditure
CC	Clear Code
CDMA	Code Division Multiple Access
CDR	Charging Records
CG	Charging Gateway
CM	Configuration Management
CN	Core Network
CS	Circuit Switched
CSSR	Call Setup Success Ratio
CSV	Comma-Separated Values
ctr	Control file extension
dat	Data file extension
DCR	Dropped Call Ratio
DHCP	Dynamic Host Configuration Protocol

EDGE	Enhanced Data rate for GSM Evolution
EIR	Equipment Identity Register
EM	Element Manager
EMS	Element Management System
ETSI	European Telecommunications Standards Institute
FER	Frame Erasure Ratio
FTP	File Transfer Protocol
GERAN	GPRS/EDGE Radio Access Network
GGSN	Gateway GPRS Support Node
GMSC	Gateway MSC
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GTP	GPRS Tunneling Protocol
GUI	Graphical User Interface
HLR	Home Location Register
HSCSD	High Speed Circuit Switched Data
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
HSUPA	High Speed Uplink Packet Access
IDE	Integrated Development Environment
IDS	Internal Data Structure
IEEE	Institute of Electrical and Electronics Engineers

IMEI	International Mobile Equipment Identity
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISUP	ISDN User Part
ITU	International Telecommunications Union
KPI	Key Performance Indicator
LAC	Location Area Code
LAN	Local Area Network
LTE	Long Term Evolution
MAC	Medium Access Control
MGW	Media Gateway
MOS	Mean Opinion Score
MS	Mobile Station
MSC	Mobile Switching Centre
MSS	MSC Server
NE	Network Element
NPM	Nokia Performance Manager
NSN	Nokia Solutions and Networks
NSS	Network Switching System
OMeS	Open Measurement Standard
OMS	Operations and Maintenance System

OPEX	Operational Expenditure
OS	Operating System
OSS	Operations Support System
P-TMSI	Packet TMSI
PAPU	Packet Access Processing Unit
PDN	Packet Data Network
PDP	Packet Data Protocol
PI	Performance Indicator
PLMN	Public Land Mobile Network
PLR	Packet Loss Ratio
PM	Performance Management
PS	Packet Switched
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RA	Routing Area
RAB	Radio Access Bearer
RAC	Routing Area Code
RAN	Radio Access Network
RANAP	Radio Access Network Application Part
RNC	Radio Network Controller
RRC	Radio Resource Control
RTP	Real Time Protocol
RTT	Real Time Traffic

SAC	Service Area Code
SAI	Service Area Identifier
SCTP	Stream Control Transmission Protocol
SFTP	Secure File Transfer Protocol
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SNR	Signal-to-Noise Ratio
SQM	Service Quality Management
SS7	Signaling System 7
TAC	Type Allocation Code
TCP	Transmission Control Protocol
TMN	Telecommunications Management Network
TMSI	Temporary Mobile Subscriber Identity
TNES	Traffica Network Element Server
TS	Traffica Server
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network
VLR	Visitor Location Register
VoIP	Voice over IP
WCDMA	Wideband Code Division Multiple Access
XML	Extensible Markup Language

1. Introduction

1.1 Main Objectives

The main objective of this dissertation is to contribute towards the identification of methods and techniques of dealing with real time and historical performance data in cellular networks. It would be interesting to integrate those types of data in a way that allows the network operator to go from the less detailed, light weight network performance data to a deeper, more detailed, real time analysis.

The next figure illustrates this challenge:

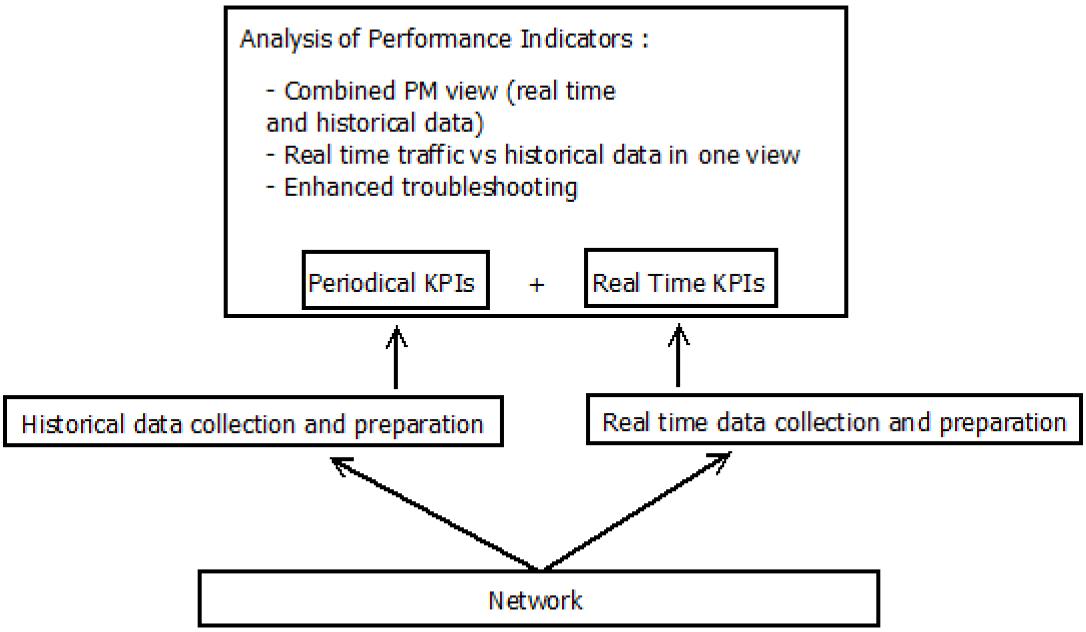

Figure 1: Main goal of this dissertation (drawn by the author)

This challenge raises several questions that will be answered throughout this dissertation. Why is this important? How can this be implemented? Which is the most relevant data to integrate and which are the most adequate procedures to be used?

In order to give an example and a more practical view over this subject, a Proof of Concept will also be implemented.

As a result of this study, we expect to achieve various goals that might represent some important advantages to telecommunications operators in the future:

- continuous control of the quality of service
- prevention of situations leading to service outage that means loss of revenue
- early recognition of upcoming problems and bottlenecks
- reduce the time consuming process of using different tools, each with its own output

1.2 Framework

Over the last decades, telecommunications networks have been continuously evolving and becoming more and more complex.

Because of these developments, the telecommunications networks became a more competitive market and were seen as a great investment opportunity.

At an economical level, the telecommunications market started to be extremely attractive but, at the same time, it also started to need a large investment of capital and became a highly intense capital market. Because of that, the telecommunications operators are continuously under pressure to reduce their costs like OPEX (Operational Expenditure) and CAPEX (Capital Expenditure), while are trying to increase their ARPU (Average Revenue Per User) [10]. This goal can be accomplished with good and effective management and operation systems and so, those issues assumed a huge importance for the operators.

With the increase of the technologies to be supported, the huge amount of data that flows in the networks and with huge networks, a good and effective management of the network is mandatory because it can save a lot of troubles and more important, money. So, several tools were designed to help in networks management improvement.

However, although there are different tools and different approaches, there are some limitations that have to be considered.

Due to current technological constraints at database level, it is not possible to save very detailed data for long periods of time, and the operator must chose to save less detailed data for a wider time frame or more detailed data for a narrower time frame. Typically, the first approach is used for PM (Performance Management) and the second one for Real Time Management.

The main issue is that it's not easy to cope with both PM and real time analysis even though it is a demanding issue for network operators.

This work will be focused on the highlighted area in the next figure, with a primary focus on MSS (MSC Server).

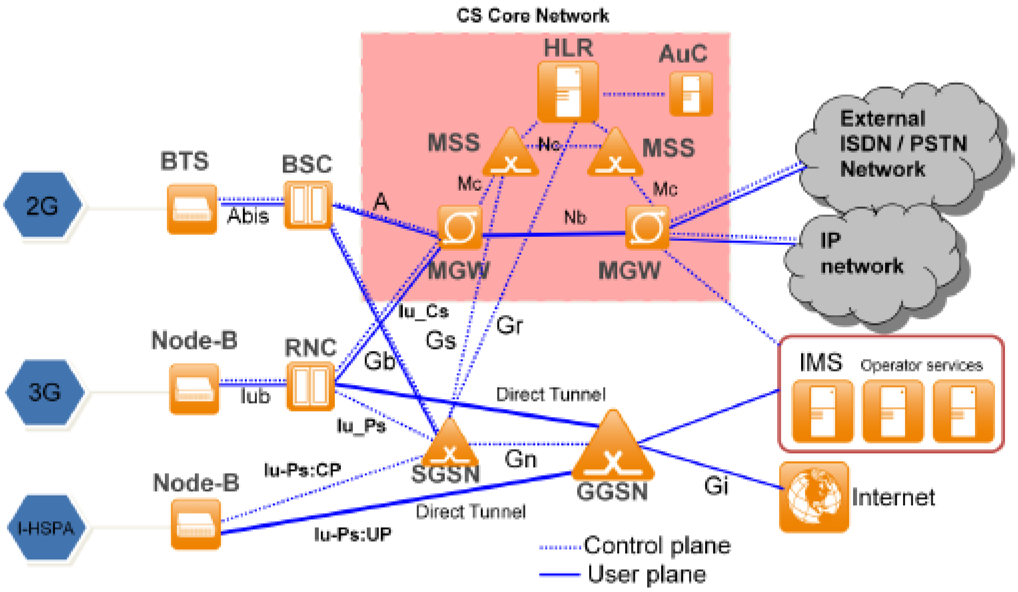

Figure 2: Main Focus of this dissertation [10]

Because of its importance in Packet switched architecture, SGSN counters and KPIs (Key Performance Indicators) will also be “lightly” studied.

1.3 Dissertation Structure

This dissertation is organized in eight chapters, references and appendixes, structured in the following way:

- **Chapter 1 – Introduction**: In this chapter it is presented an overview of the subject of this dissertation and its main goals and advantages are well identified.

- **Chapter 2 – Evolution of Cellular Networks**: In this chapter it is presented an evolution of the telecommunications networks as well as the main characteristics of the existent technologies.

- **Chapter 3 – Cellular Networks Dynamics:** Some call setup procedures are presented. Both voice calls and data calls are referred. This chapter introduces several concepts that are fundamental for the understanding of this dissertation like NEs (Network Elements) exchanged messages, as well as concepts like IMSI and TMSI, location updates, handovers and some network protocols. Besides that, the need and the appearing of KPIs are also presented.

- **Chapter 4 –Nokia Management tools**: In this chapter, some Nokia tools that are important to this work are studied in more detail. NetAct, NPM and Traffica architecture and main characteristics are the main focus of this chapter. It is also studied a Traffica application called CQIM because some concepts may be important and it may serve as a guide for following chapters.

- **Chapter 5 - Counters and KPIs (MSS related)**: In this chapter is presented a real time KPIs proposal based on some Traffica MSS related counters.

- **Chapter 6 – Other Possible Features**: In this chapter, it is presented a chapter 5 similar study, but focused on MGW and SGSN counters. It is also presented a possible way to know some important information per user equipment (brand and model) type.

- **Chapter 7 – PoC Implementation**: This chapter is about the integration of the previously presented real time KPIs in NPM. It contains more practical information and the main goal is to present a proof of concept of that integration.

- **Chapter 8 – Conclusions and Future Work:** This chapter presents the main conclusions of this dissertation, as well as some suggestions for future work.

2. Evolution of Cellular Networks

2.1 Introduction

This dissertation is related to a specific case of wireless communications systems that are called cellular systems.

In general, the wireless communications systems are constituted by the following components presented in the next figure.

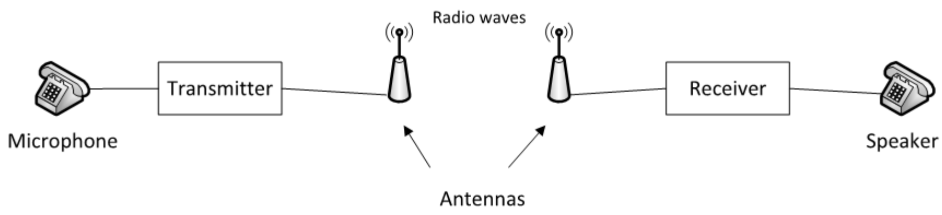

Figure 3: Basic Wireless Communication System [based on 2]

- Microphone: is responsible for the conversion of voice in an electrical signal
- Speaker: is responsible for the conversion of the electrical signal in an acoustic signal
- Transmitter: transmits the signals generated by the microphone until the receiver
- Receiver: Receives and interprets the signals
- Antenna: converts the electrical signals into radio waves and receives radio waves to posterior conversion in electrical signals

The cell concept arose with the appearance of the so called ‘First Generation Mobile Systems’, and it represents an area of transmission. Hence, the technology came to be known as cellular technology while the phones were called cell phones.. The cells may be omnidirectional, which means that they present a radius angle of 360º, or may be divided in sectors. If they have 3 sectors, they will have a radius angle of 120º, as it is possible to observe in the next figure.

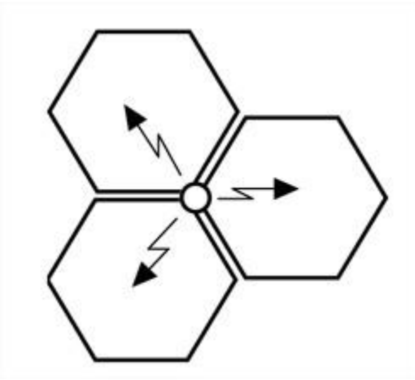

Figure 4: 3-sector cell site [27]

These 3-sector cells are usually utilized in areas with medium to high traffic density, and are the most common configuration.

The biggest advantages of the cellular structure are the following [57]:

- Possibility to reuse the spectrum, which translates into higher capacity and a larger number of users
- Lower transmission power
- More robustness
- Each base station can be adapted to the area where it is located

The cellular technology evolution has been going on since the late 1950s, though the first commercial systems came into being in the late 1970s and early 1980s [57]. In the next sections, an overview of cellular technologies and networks evolution is presented.

2.2 First Generation

The first generation systems were almost purely analog. These first generation wireless systems only provide analog speech and inefficient, low-rate data transmission between the base station and the mobile user [6].

One example of this first generation is AMPS (Advanced Mobile Phone Service) and it was first built by engineers from AT&T Laboratories. The AMPS operation mode is the following [23]:

- Subscriber initiates call by keying in phone number and presses send key
- Network verifies number and authorizes user
- Network issues message to user's cell phone indicating send and receive traffic channels
- Network sends ringing signal to called party
- Party answers; network establishes circuit and initiates billing information
- Either party hangs up; network releases circuit, frees channels and completes billing

Besides the obvious limitations of first generation systems, most of them were incompatible with one another, which resulted in serious limitations because users of a given network were exclusively subscribers of a given operator. They were also very expensive and presented very limited mobility.

After this, telecommunications evolved to a called 2G or GSM (Global System for Mobile communications). The creation of GSM began to be prepared in 1982 [1], but it took a while before the first connection was established. The first connection in the GSM network was set up in 1991 and this year marks the onset of the dynamic development of cellular telephony we are experiencing today [2]. Its success has motivated the development of new services and technologies for cellular telephony. This research led to a standard for the third-generation telephony (UMTS). As the research in this area has continued, LTE (Long Term Evolution) has appeared.

This evolution will be studied in the next sub-chapters.

2.3 *GSM*

2.3.1 Introduction

As it was previously mentioned, the first generation of mobile phone systems consisted in analog systems. The designers of those systems did not realize that cellular telephony would become a universal and popular service and thus, the systems in question, had a rather limited capacity.

GSM is the so-called second generation (2G) and just for curiosity, GSM originally designated the 'Group Spécial Mobile' because that was the name of the organization that was created to develop a standard for a mobile telephone system [1].

The GSM standard was developed in order to create a uniform and open cellular mobile phone system.

One of the major objectives was to develop a digital system that would enable voice transmission, SMS, data transmission and that would be able to handle international roaming.

The access to the radio link uses frequency division multiple access (FDMA) and time division multiple access (TDMA) simultaneously. Usually, up to eight users share one frequency by time splitting, and one antenna supports up to twelve frequencies. Every user is assigned a certain timeslot on a certain frequency.

- FDMA (Frequency Division Multiple Access)

This technique is the oldest and it is mainly used in analog systems. The available bandwidth is divided in non overlapping channels or frequencies.

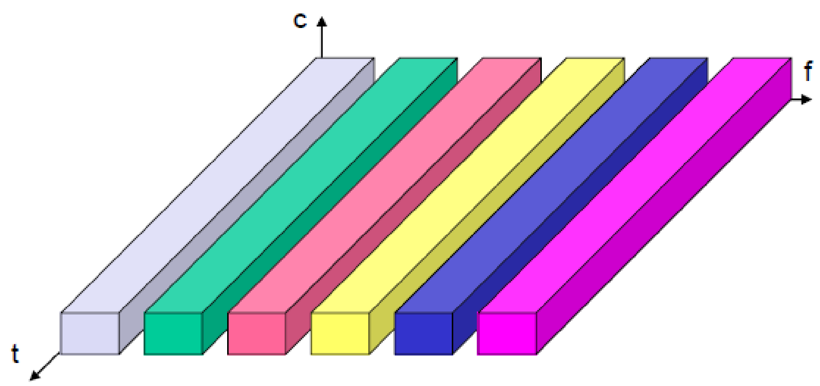

Figure 5: FDMA graphic representation [26]

Making a simple analogy with people talking in a house, this corresponds to different persons speaking in different rooms to avoid interference [26].

- <u>TDMA (Time Division Multiple Access)</u>

In this case, the time axis is divided in slots that are allocated to the different channels/ users and one channel uses the whole spectrum during a given time.

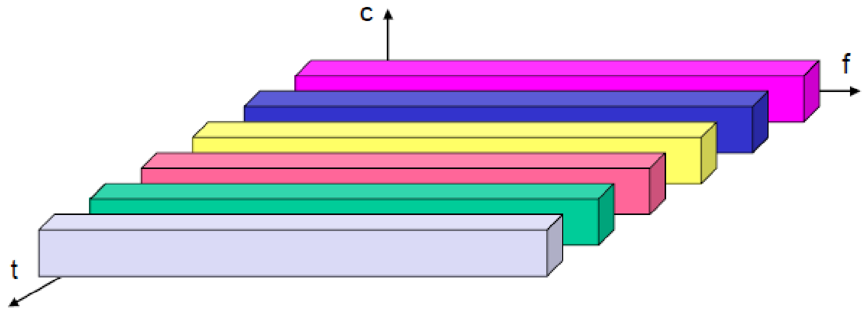

Figure 6: TDMA graphic representation [26]

Making a simple analogy with people talking in a house, this corresponds to people speaking in the same room but at different times to avoid interference [26].

- <u>Time and Frequency Multiple Access</u>

One channel uses a given band within a given time interval and hops between bands ("frequency hopping"). Because of that, it is also known as TDMA with frequency hopping.

This is the used technology in GSM.

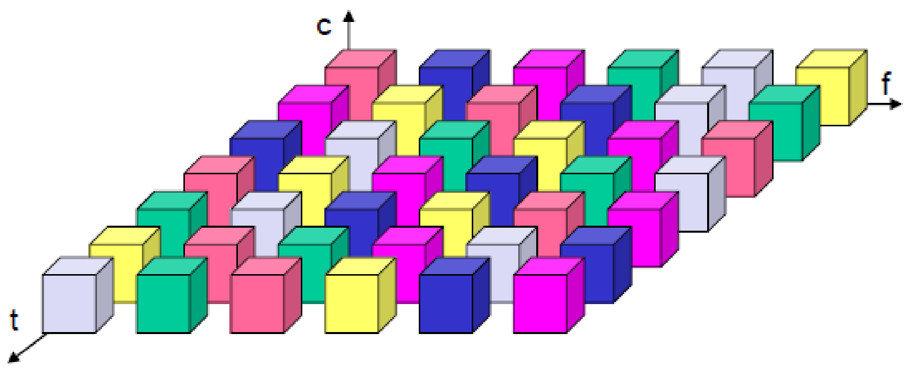

Figure 7: Time and Frequency multiple access graphic representation [26]

2.3.2 System Architecture

The GSM network is formed by open and standardized interfaces. Because of that, the operators can combine elements from different companies which results in a very flexible architecture. A GSM architecture that belongs to a telecommunications operator is called PLMN (Public Land Mobile Network).

In the GSM system, the main components are:

- ➔ Mobile Station (MS)
- ➔ Base Station System (BSS)
- ➔ Network Switching System (NSS)
- ➔ Operations and Maintenance System (OMS)

The next figure represents the most important elements of a GSM network:

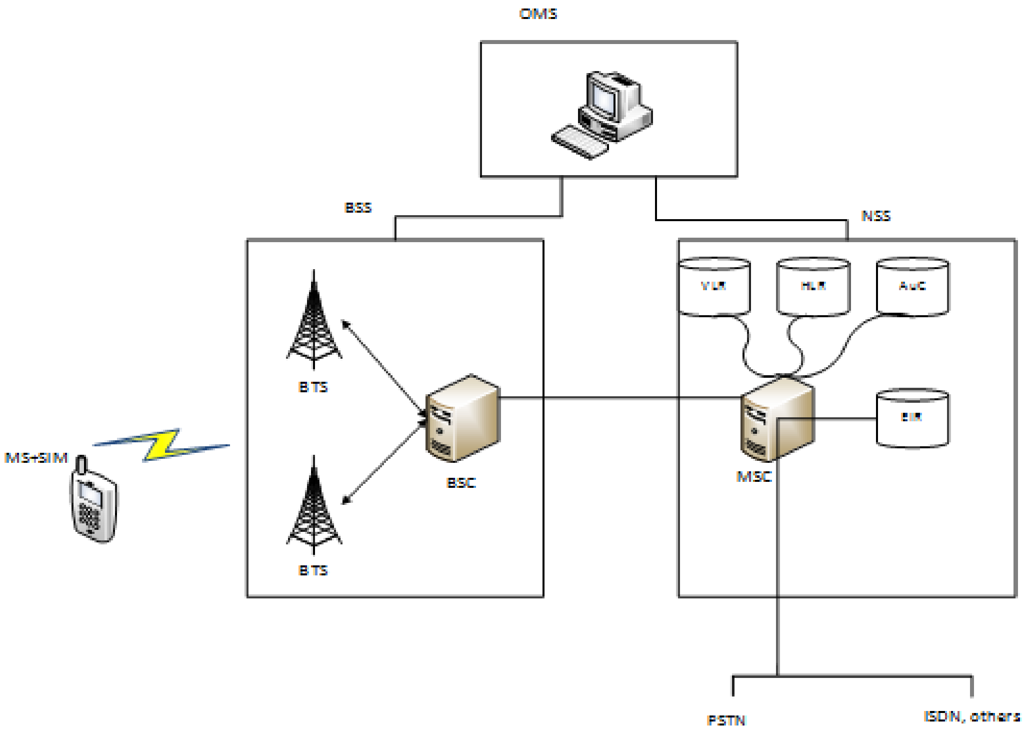

Figure 8: Structure of a GSM network (based on [2])

- <u>Mobile Station (MS)</u>

Includes the Mobile Equipment (ME) and the Subscriber Identity Module aka SIM. The first one is responsible for the connection between the subscriber and the GSM network and each one has an identification number known as IMEI (International Mobile Equipment Identity).

The SIM is a smart card that is internally connected to the ME, and has much information about the Mobile Stations like subscriber identity, PIN, subscription information, security algorithms, last visited location area, etc [2].

- Base Station System (BSS)

This system is responsible for the connection between the MS and the Mobile services Switching Centre (MSC). A BSS is formed by [2]:

- ➔ Base Station Controller (BSC): manages radio resources allocation to particular mobile stations; controls the setting-up and the release of calls; decides on handover of connections between particular cells; regulates the power, the time alignment and time advance of signals transmitted by mobile stations.

- ➔ Base Transceiver Station (BTS): Provides the air connections with the MS. It is always interconnected with the BSC. Basically, it is constituted by Radio Frequency hardware and Antennas.

- ➔ Transcoder (XCDR): Converts the voice signals from the MSC (64 Kbits/s) into a signal that respects the GSM standard rules. This conversion may happen in the MSC or BSC or BTS.

- Network Switching System (NSS)

Is constituted by [2]:

- ➔ Mobile service Switching Centre (MSC): It is the basic element of the NSS. Its basic task is to control and regulate services provided by the system, circuit switching and gathering billing information.

- ➔ Home Location Register (HLR): Is a central database that contains details of each mobile phone subscriber authorized to use the GSM network.

- ➔ Visitor Location Register (VLR): Keeps information concerning mobile stations available in the area of one, or several MSC. Keeps a copy of subscribers' information during a predefined time.

- ➔ Authentication Centre (AuC): Its main tasks are to generate sets of keys used in the encryption of transmission, identify the mobile station and the network, and to control and regulate the integrity of transmitted data.

- ➔ Equipment Identity Register (EIR): Is a database that keeps a list of numbers identifying a given mobile station.

- ➔ Interworking Function (IWF): Its basic task is to operate the protocol conversions.

- ➔ Echo Canceller (EC): As its name indicates, its task is to eliminate the echo that is present in some connections.

- <u>Operations and Maintenance System (OMS)</u>

This system allows the remote and centralized administration, supervision and maintenance of the elements that integrate a GSM network. It is divided in two subsystems: Network Management Centre (NMC) and Operations and Maintenance Centre (OMC) [2].

Those different elements that compose GSM network are connected via some interfaces which provide services implementation and interworking between them.

The next table presents some interfaces and the elements they connect.

Interface Name	Interconnected Elements
Air interface(Um)	MS-BTS
Abis	BTS-BSC
A interface	BSC-MSC
B interface	MSC-VLR
C interface	MSC-HLR
D interface	HLR-VLR
E interface	MSC-MSC
F interface	MSC-EIR
G interface	VLR-VLR

Table 1: GSM interface types [2]

A brief description of these interfaces is presented next [2]:

- <u>Air interface (Um)</u>: this interface is also known as radiofrequency interface and it is responsible for the interconnection between the MS and the BTS. It provides the physical and logical channels that are needed for call processing in the air interface

- <u>Abis</u>: it is used to support the services that are offered to the subscribers. It also allows the control of the equipment and the allocation of radiofrequency resources in the BTS

- <u>A interface</u>: it is used to transport information like BSS managing information, call processing, allocation of terrestrial resources and mobility management

- <u>B interface</u>: it is responsible for the interconnection between MSC and VLR and is used in management of the subscribers database that are associated with that VLR

- <u>C interface</u>: this interface is used when the MSC needs to interrogate the HLR in order to get some routing information

- <u>D interface</u>: it is used for exchanging information related to MS localization or subscriber management

- E interface: it is used in handover procedures between MSCs

- F interface: it is used to verify the IMEI and thus see if the MS is "authorized" to use the network resources

- G interface: it is used when a MS moves from one VLR to another. Its main task includes IMEI recovery as well as authentication parameters recovery

2.3.3 Evolution towards third generation

Before reach the 3G, the GSM architecture experienced some changes that allowed the telecommunications evolution. It is possible to identify at least three intermediate stages/improvements: HSCSD, GPRS and EDGE. They were very important in this evolution insofar as they introduced new features and concepts.

The HSCSD (High Speed Circuit Switched Data) is an enhancement to Circuit Switched Data, which is the original data transmission mechanism of the GSM mobile phone system. One innovation is that HSCSD allows different error correction methods to be used for data transfer. Other innovation in HSCSD is the ability to use multiple time slots per user at the same time, which can provide an increase in maximum transfer rate.

GPRS (General Packet Radio Service) is a packet-oriented transport service, for data network connections (Internet). GPRS features:

- Better transmission bit rates
- Allows burst communications ("immediate" connections)
- New network applications
- New billing mechanisms, as by traffic for an example. Before GPRS, users were charged by connection time, whether data was actually transmitted or not. With GPRS, because it is packet oriented, charging is made by counting the packets and the user only has to pay for the real amount of transmitted data.

In terms of architecture, GPRS defines new entities like SGSN and GGSN, data packets are transmitted by tunnel mechanisms, uses GTP (GPRS Tunneling Protocol) for tunnel management and introduces changes in the logical channels and how they are managed.

These new entities (SGSN and GGSN) would play an important role in the upcoming technology to be studied.

SGSN monitors the user location and provides security and access control functions. GGSN provides routing information of the connected users to the Packet Switched network and it provides interconnection with external Packet Switched networks as the Internet, for an example.

EDGE (Enhanced Data rate for GSM Evolution) is another stage to be considered.

The main objective of EDGE was to increase the data bitrates. That means new modulation and link adaptation but do not involve big changes in existing GPRS networks.

Summarizing EDGE:

- Was announced as low-cost 3G
- It is considered as a 2.5G evolution of GSM
- Improved GPRS structure but retained the basic structure
- Improved data rates
- Improved spectrum efficiency
- Higher Capacity of the network
- Supports GMSK and 8-PSK
- Requires some changes in BTS transceivers design

All of these new features led to a new idea for a new technology – UMTS (Universal Mobile Telecommunications System).

2.4 UMTS

2.4.1 Introduction

In 1989, a document from the International Telecommunication Union (ITU), shown its ideas about the next cellular systems, also called 3G. That document had the standards that would be provided by the new system, named at the time IMT-2000.

It was also decided that the UMTS system should provide the users with many different types of services, including those that would only be developed in the future. Their implementation should be easy and cheap, and should be possible without costly development of the system.

The next table shows the initial planning for UMTS:

1998-1999	Radio Interface definition
2000	First demonstrations of 3G systems
May 2000	IMT-2000 specifications validation by ITU-R
2000-2001	3G licenses allocation in Europe
Mid 2001	First 3G networks opened in countries such as Japan, based on first 3G specifications
Mid 2002	3G terminals available (first specifications)
2002	3G pilot networks in Western Europe
2002-2003	3G applications development
Mid 2004	3G commercially available

Table 2: Development initial planning [22]

The main objectives and features of UMTS were [22]:

- Wideband
- Service integration
- Packet access
- Techniques for capacity enhancement like multi-user detection, interference cancellation, adaptive antennas, MIMO, etc.
- Inter System (GSM-3G) and inter-frequencies handover

The transmission of data became a very important issue, as it is possible to observe in the next figure:

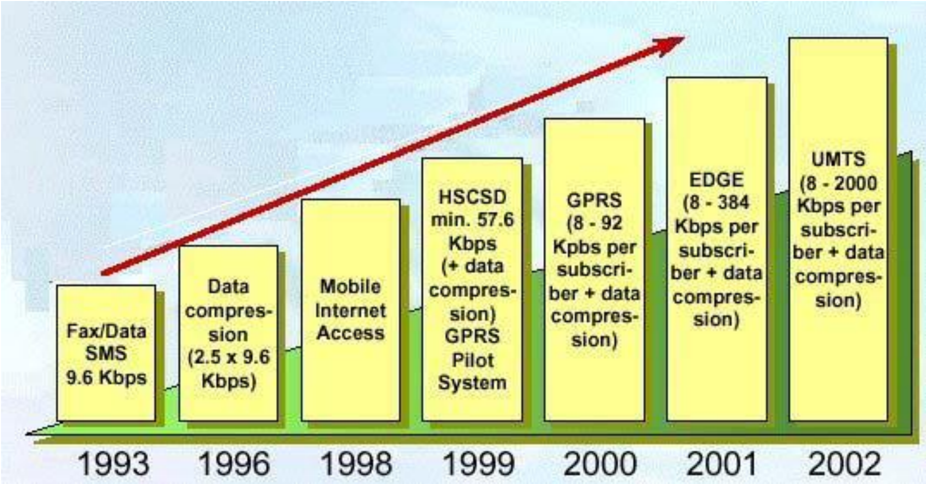

Figure 9: Data transmission evolution [22]

Because of this growing interest in Data, the packet switched domain elements that were previously referred as SGSN and GGSN would become very important in UMTS.

2.4.2 System Architecture

It was decided that during the first years of its development, the system would use the core network of existing 2G systems, as the GSM systems for example. This decision led to a great development of the existing core network of the GERAN (GSM EDGE Radio Access Network, and a new kind of radio network called UTRAN (UMTS Terrestrial Radio Access Network), using the wideband code division multiple access (WCDMA) radio interface. This is a combination of CDMA and a wide frequency band. In this technique all users transmit on the same frequency.

- <u>CDMA (Code Division Multiple Access)</u>

In this case, one channel uses a code that is unique and distinct, which allows the "separation" from the other channels. This means that all channels make use of the whole spectrum at the same time.

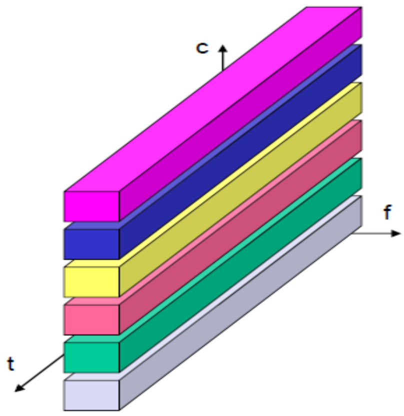

Figure 10: CDMA graphic representation [26]

Making a simple analogy with people talking in a house, this corresponds to everyone speaking in the same room at the same time but using different languages to “create” a filtering effect [26].

The WCDMA presents some important advantages:

- Larger capacity and coverage, keeping compatibility with 2G
- Supports the flexibility required with multiple parallel connections
- Efficient Packet Access
- Interaction between asynchronous base stations (FDD), hierarchical cell structure, adaptive antennas and TDD mode for asymmetric environments, which are advantages to the operator

The FDD and TDD concepts were previously mentioned and correspond to multiplexing modes that can be defined as:

FDD (Frequency Division Duplex) ⇨ spectrum sharing based on the usage of different frequencies; good for symmetric services in large areas.

TDD (Time Division Duplex) ⇨ spectrum sharing based on timeslots; good for asymmetric services; require timing synchronism.

Note that symmetric systems are those in which data speed or quantity is the same in both directions, otherwise they are asymmetric.

UMTS system should be flexible enough to accommodate various types of services in the future, and its introduction should not entail costly expansion of the network or stoppages in its operation.

The UMTS Release 1999 was the first version of the UMTS network architecture and it was approved by 3GPP (Third Generation Partnership Project) in March 2000.

The UMTS basic network architecture consists of the following elements:

➔ User Equipment (UE)
➔ Core Network (CN)
➔ Universal Terrestrial Radio Access Network (UTRAN)

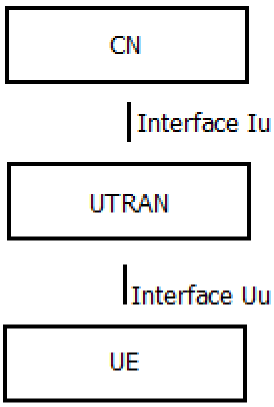

Figure 11: Basic UMTS architecture [2]

The Iu and Uu interfaces play an important role in this architecture.

Uu is responsible for the control of the connection between the MS and the Node B.

The Iu interface is located between the RNC (Radio Network Controller) and the MSC for circuit-switched traffic (IuCS) and between the RNC and the SGSN for packet switched traffic (IuPS). Iu provides the connection to "classic" voice services, and at the same time connection for all kinds of packet services. It also plays a vital role in the handover procedures in the UMTS network [57].

The next figure presents the UMTS architecture in more detail.

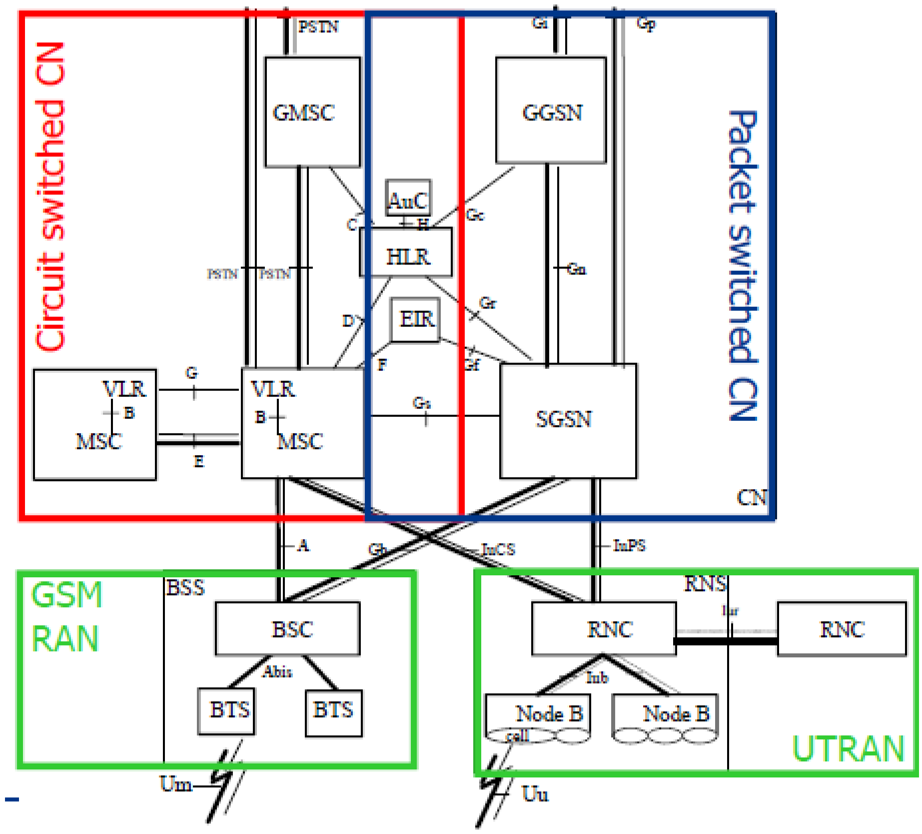

Figure 12: UMTS network architecture (Rel.99) [7]

As it is possible to observe, the compatibility with 2G is a really important issue, and here we have the two technologies in a "healthy coexistence".

The UTRAN architecture is formed by a Radio Network Subsystem (RNS) that is connected to the Core Network.

The RNS is constituted by the RNC and the node B.

RNC is the 3G correspondent to BSC and its main functions are [1]:

- resource allocation to particular mobile stations
- radio network admission control
- power control
- Node B management

The Node B is the 3G correspondent to BTS and has the following functions among others [1]:

- channel coding
- data interleaving
- signal spreading
- data speed adjustment and modulation
- power control

The circuit switched core network elements are the same in this release of UMTS and GSM, and were mentioned and explained in previous sub section. It is also important to mention that GMSC is a gateway MSC and as its name indicates, it is a MSC that is connected to a called party that belongs to other networks (like fixed networks, as an example).

The packet switched core network introduces SGSN and GGSN that were “inherited” from GPRS. Their main functions were also previously presented.

Besides these characteristics, following UMTS releases have introduced other features that are worth pointing out.

The UMTS network architecture in version R4 introduces changes in the core structure, because the aim is to have networks that can operate exclusively on IP protocol.

One important change was the inclusion of MGW (Media Gateway). In previous release, the MSC was responsible for the control plane and the user plane. With MGW, these planes were separated, and MSC continued to be responsible for the control plane but the user plane began to be “commanded” by MGW.

The new architecture is illustrated in the next figure:

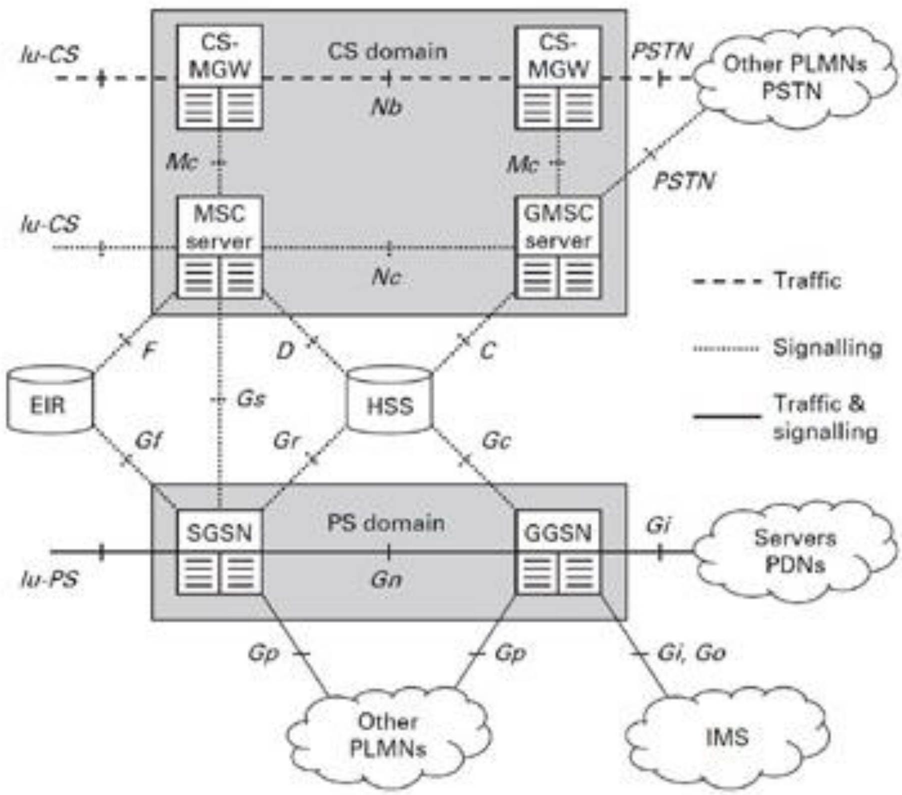

Figure 13: UMTS Following Releases [63]

Besides architectural changes, MSC also started to be known as MSS (MSC Server).

As it is possible to observe, there is a division between the Signaling (that is considered control plane) and the Traffic (that is considered user plane). The first flows through MSS and the second flows through MGW.

So, MSS (new) main functions are [64]:

- Control MGW
- Set up and maintain calls
- Create connections between MGWs
- Store and interact with subscriber info (VLR)
- Create, store and forward CDRs (Charging Data Records) for post-processing
- Take care of mobility management issues

On the other hand, MGW handles [64]:

- Data and media processing
- Issues like voice coding/decoding and echo cancellation
- QoS related issues

After this release, some upgrades were made, and the most important is known as HSPA (High Speed Packet Access). This was an upgrade to WCDMA networks and it was used to increase packet data performance. The introduction of HSPA was done in two steps: HSDPA (High Speed Downlink Packet Access) was introduced in 3GPP release 5 and HSUPA (High Speed Uplink Packet Access) was introduced in release 6. The key modifications introduced by HSDPA were: introduction of a shared data channel multiplexed in time; introduction of new modulation (16QAM) and coding schemes; modification of the MAC protocol architecture to enable faster response to changes in user demands and radio conditions [58]. HSUPA includes a set of new features very similar to the ones introduced by HSDPA but in the uplink direction. The main goal was to provide significant enhancements in terms of user experience with increased throughput, lower latency and higher capacity [58]. The combination of these 2 features (HSDPA and HSUPA) is referred to as HSPA.

Other changes in the R5 and R6 versions involve the integration of HLR and AuC server in one single device called the Home Subscriber Server (HSS), and the introduction of the IP Multimedia System (IMS), that is a device responsible for allowing access to services based on the IP protocol (as VoIP as an example). These features are also represented in figure 13.

2.5 LTE

2.5.1 Introduction

The number of subscribers to mobile telecommunications system has continued to increase, as well as the average call time and the amount of data transmitted per user. Furthermore, a number of new services have emerged and well-established services were perfected, experiencing an ever-growing interest among subscribers. Besides that, the arrival of mobile terminals with much more advanced capabilities for images, audio, video, email and office applications fueled this growth. With these facts, is easy to understand the need to develop a new system that would be able to handle all of these requirements. The Third Generation Partnership Project Long-Term Evolution (3GPP LTE) appears in this context.

The most important requirements identified for the LTE systems were [1]:

- cost reduction in network data transmission;
- reduction in setup time and round trip delay;
- improvement in functioning of quality of service mechanisms for various services;
- focus on services using the IP protocol;
- increase the transmission rate to over 100 Mbps in the downlink and 50 Mbps in the uplink direction;
- flexibility in the use of existing and new spectral resources;
- possibility of carrier allocation with different bandwidth, ranging from 1.25 to 20 MHz.

2.5.2 System architecture

It was assumed that LTE systems would have to satisfy even higher requirements and should have low construction and maintenance costs. So, the system architecture was simplified.

In LTE Release 8, all radio protocols, subscriber mobility management, compression of headers and packet retransmissions have been located in the base station labeled E-UTRAN Node B (eNodeB). This base station also includes all algorithms and functions that in previous versions were located in the radio network controller. The reason for distributing the “intelligence” to the base stations is to speed up the connection setup and reduce the time required for handovers. Another advantage is that the MAC protocol layer can be terminated in the base station, which enables faster adjustments of air interface, which in turn enables more efficient use of the radio resources [1].

The LTE architecture is formed by the following elements:

➔ eNodeB (E-UTRAN Node B)
➔ eGW (access gateway)
➔ MME (mobility management entity)
➔ UPE (user plane entity)

These elements can be observed in the next figure:

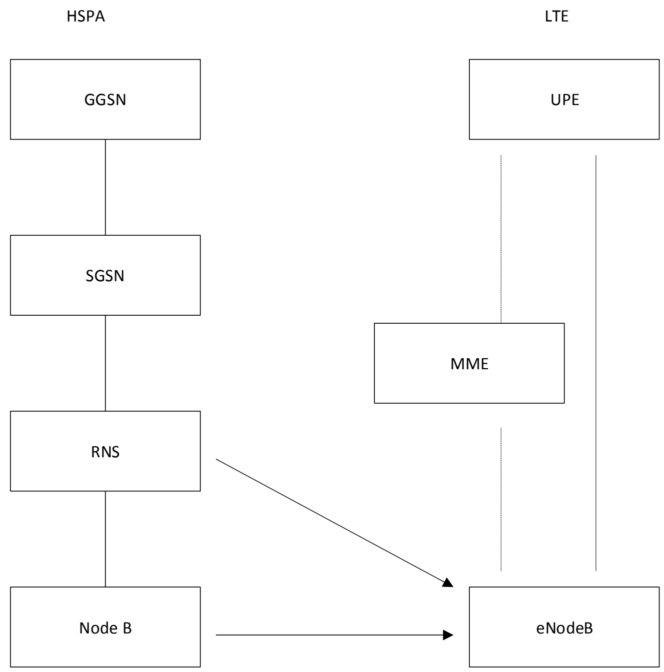

Figure 14:LTE vs HSPA (UMTS) [1]

The MME is responsible for the management and context storage for the control of users' terminals, authorization procedures for terminals, and mobility management schemes for terminals [1].

The tasks of UPE include management and subscriber terminal context storage, encoding, securing integrity of data blocks and automatic repeat request to reduce data block discard. Individual blocks located in network nodes communicate with one another and with external networks [1].

The blocks cooperate with base stations, which carry on all functions related to radio transmission [1].

2.6 Summary

The next table represents a simple summary of the previously mentioned technologies.

Generation	Access Protocols	Key Features	Level of Evolution
1G	FDMA	Analog, primarily voice, less secure, support for low bit rate data	Access to and roaming across single type of analog wireless networks
2G and 2.5G	TDMA and FDMA, CDMA	Digital, more secure, voice and data	Access to and roaming across single type of digital wireless networks and access to 1G
3G and 3.5G	CDMA2000, W-CDMA	Digital, multimedia, global roaming across a single type of wireless network, limited IP interoperability, 144kbps to several Mbps	Access to and roaming across digital multimedia wireless networks and access to 2G and 1G
4G	OFDMA	Global roaming across multiple wireless networks, 10Mbps to 100Mbps, IP interoperability for seamless mobile Internet	Access to and roaming across diverse and heterogeneous mobile and wireless broadband networks and access to 3G, 2G and 1G

Table 3: From 1G to 4G [22]

Note that the future work presented in this document is more related to UMTS and thus, UMTS terms and definitions will be mainly used.

3. Cellular Networks Dynamics

Cellular Networks in general, and 3G systems in this particular case, allows offering the user a large variety of services and applications. Voice calls, SMS, data calls, interactive gaming, etc. are just a few examples and it is important to understand the different types of traffic that flow in the network.

Regarding the traffic that is related to calls, it is possible to observe that there are two different planes in this kind of networks. We have the control plane and the data plane. We can also see the two domains that are packet switched domain and the circuit switched domain.

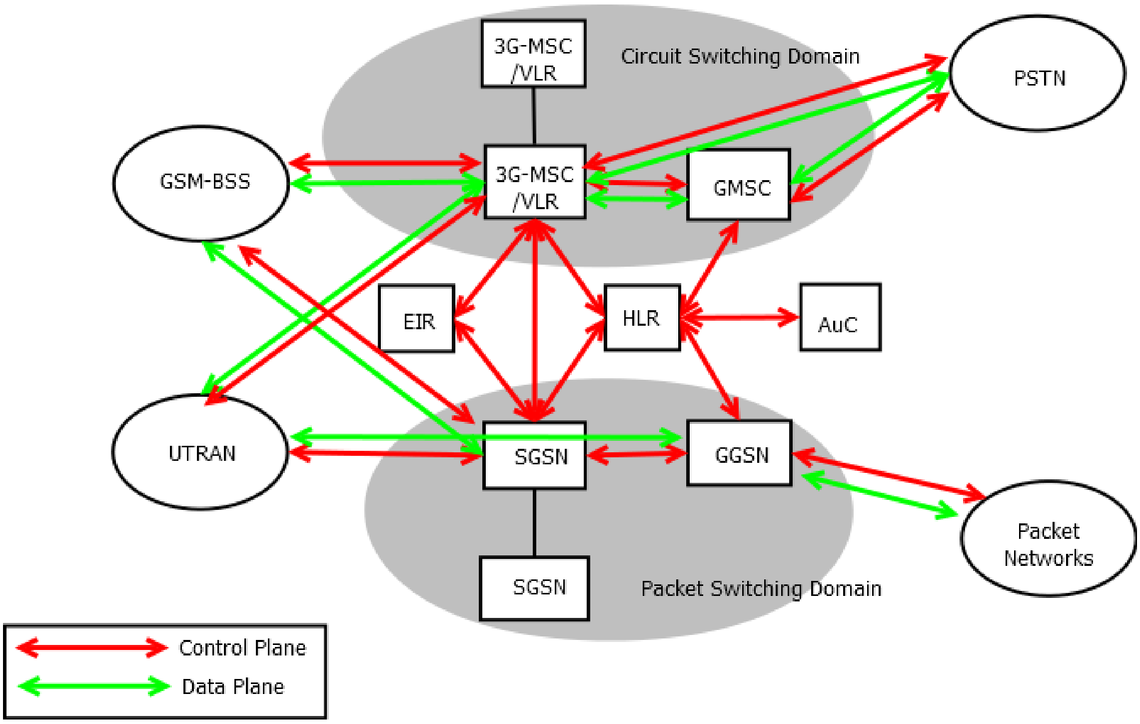

Figure 15: UMTS R99 version (created by the author based on [1])

The main service of circuit switched domain is the voice calls service and the main service of packet switched domain is the data calls service. Although there are other services, these are the most important and those procedures will be deeper analyzed.

3.1 *Set-Up Procedures*

3.1.1 Data Call Set-up procedure

The packet switched domain is illustrated in the following figure. It is possible to observe the basic elements that are part of that domain as well as their connections.

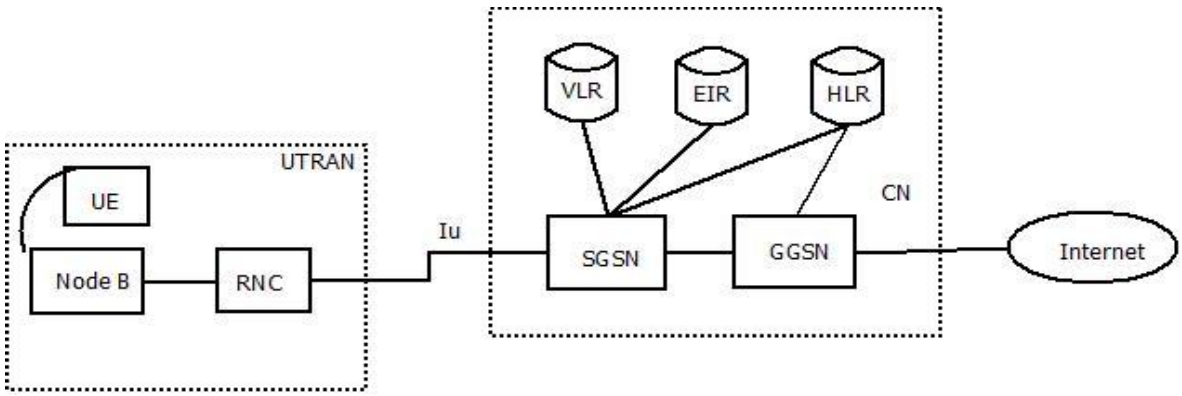

Figure 16: Packet Switched domain in UMTS (Created by the author)

GPRS is the packet core network of UMTS. It includes two network nodes: the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). As it was previously presented, the SGSN monitors the user location and provides security and access control functions, and the GGSN provides routing information of the connected users to the Packet Switched network and it provides interconnection with external Packet Switched networks as the Internet, for an example.

The mobile station (MS), which might be a smart phone, a laptop with a 3G modem, or any other 2G/3G enabled device, establishes a wireless connection with the nearest node B of a Public Land Mobile Network (PLMN) to which the user is a subscriber. After authentication of the mobile user has taken place, an IP data connection is established (tunneled) between the MS and the GGSN (Gateway GPRS Support Node), going through the node B, the RNC and the SGSN (Serving GPRS Support Node). The MS gets assigned an IP address by the GGSN during the establishment of the tunnel. The MS sends all IP packets through the tunnel so that they are received by the GGSN. The GGSN “decapsulates” the IP packets coming from the MS and routes them to the Internet. Conversely, the GGSN receives from the Internet all the packets going to the MS, encapsulates them, and sends them to the MS through the previously established tunnel.

This tunneling concept means that the elements aren´t aware of the packets content. They just carry them between two points of the network.

The next figures illustrate the attach procedure, routing area update and the PDP (Packet Data Protocol) context activation. These procedures are needed to authenticate the Mobile station and create the tunnel, and therefore play a fundamental role in data call setup.

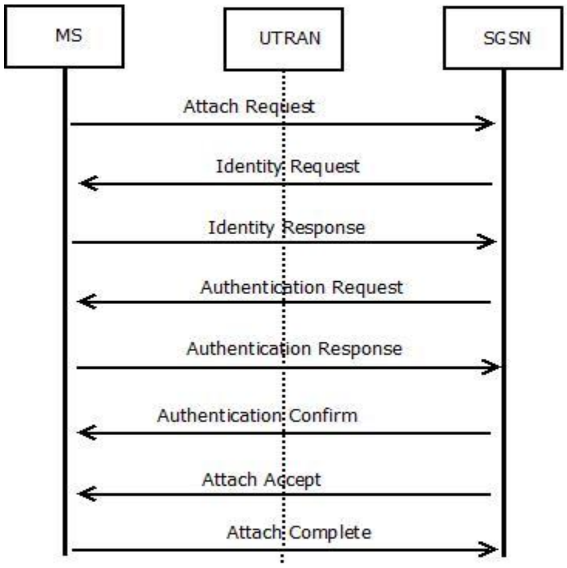

Figure 17: Attach Procedure [6]

In this procedure, a MS sends an attach request to SGSN. The attach request message contains information such as the MS' identity like IMSI or P-TMSI and the attach type to be executed, for example. The SGSN will send an identity request message to the MS if it uses P-TMSI in its attached request message and has changed a SGSN since the last detached, and the MS will respond with an identity response message. After this, authentication messages are exchanged and then, the SGSN sends an attach accept message. This message contains the newly allocated P-TMSI, P-TMSI signature and the radio priority for SMS. The MS ends this procedure with an attach complete message [6].

After the GPRS attach procedure, a MS needs to perform a routing area update procedure if this is the new SGSN it is connecting to. This procedure is shown in the next figure:

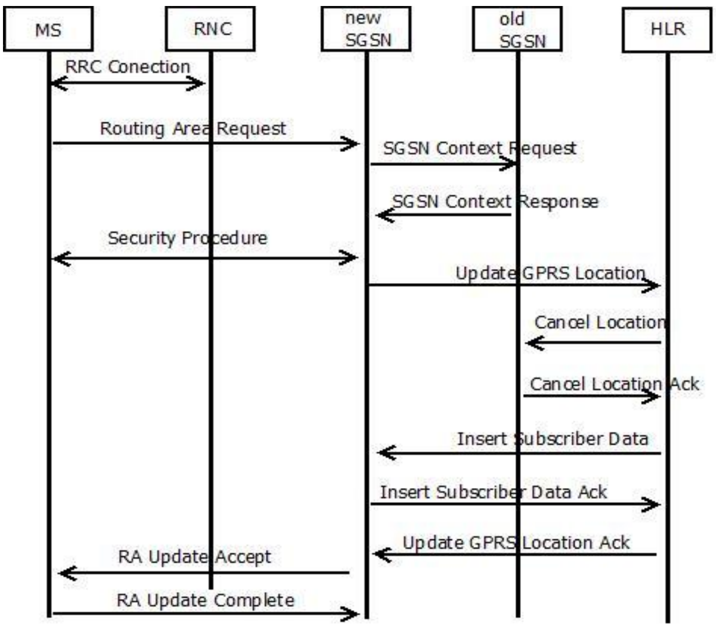

Figure 18: Routing Area Update [6]

A RRC connection is established between the MS and the Serving RNC. Then, the MS sends a Routing Area Update Request message to the new SGSN. If there was an old SGSN, the MS needs to provide the old Routing Area Identity and old P-TMSI information to the new SGSN. The new SGSN sends a context request to the old SGSN in order to get the MS' IMSI. After the response, the new SGSN may invoke security procedure to authenticate the MS. Next, the new SGSN informs the HLR of a change in SGSNs and the HLR sends a "Cancel location" order to the old SGSN to detach the MS' IMSI. The HLR sends subscription data to the new SGSN, which acknowledges receipt of this subscriber data before HLR acknowledges the GPRS location update to the new SGSN. Then, the new SGSN sends a Routing Area Update Accept message which includes the new P-TMSI to the MS and it responds with a RA Update Complete message acknowledging receipt of the new P-TMSI. The new SGSN can release the signaling connection to the serving RNC and the serving RNC may release the RRC connection if it is not needed to maintain a CS domain connection [6].

To initiate a data session, the MS needs to perform a PDP context activation procedure, which is illustrated in the next figure:

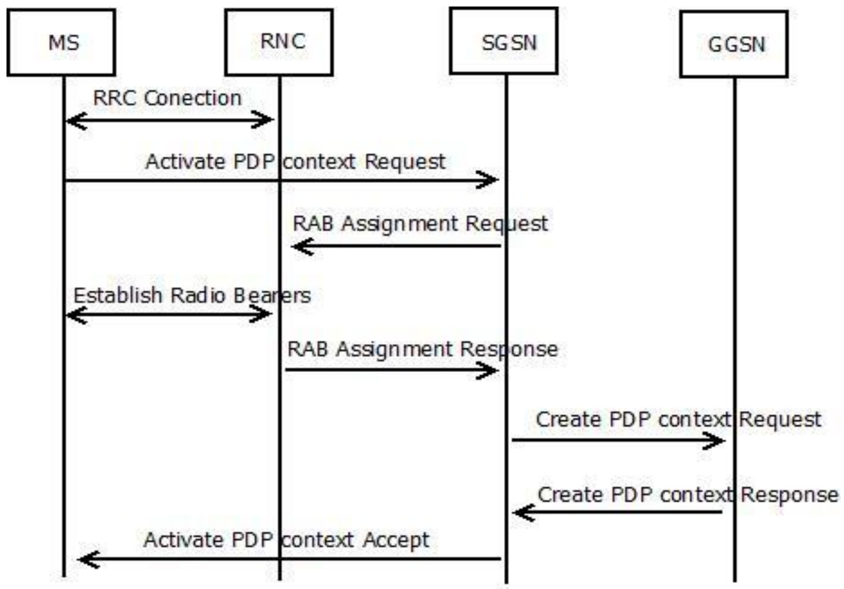

Figure 19: PDP context activation [6]

First, the MS establishes a RRC connection with the serving RNC. Then, the MS sends an activate PDP context request message to the SGSN. The SGSN requests the setting up of Radio Access Bearers (RABs) with the radio access network via a RAB assignment request message to the serving RNC. The RNC, the node B and the MS set up the RABs. Then, the RNC sends a RAB assignment response message back to the SGSN and a GTP tunnel between the RNC and the SGSN is "created". The SGSN sends a create PDP context request to the GGSN to set up a PDP context since a connection to an external Packet Data Network is required. The GGSN allocates a PDP address (dynamic IP assignment) and sends a create PDP context response back to the SGSN. Finally, the SGSN sends an activate PDP context accept message to the MS with the assigned PDP address [6].

3.1.2 Voice Call Set-up procedure

In this section, the focus is the Circuit Switched Domain.
Considering that an A subscriber wants to call to a B subscriber:

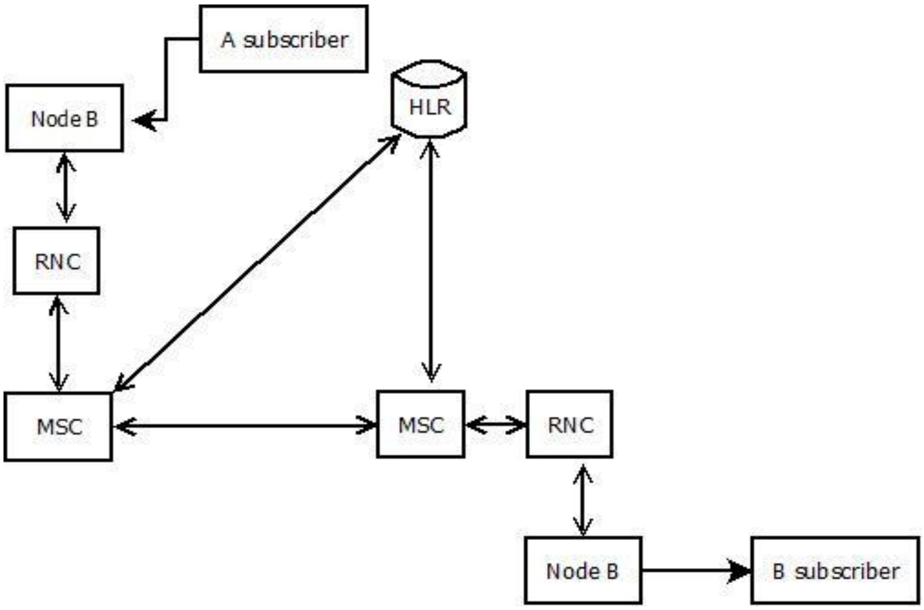

Figure 20: Simplified Call Set-Up procedure (created by the author)

Initially, the call request reaches the RNC from the node B and it is forwarded to the MSC. After the call is established, RNC will perform the decoding of the call.

The MSC checks A number and checks B number too. When the call is established, MSC also handles the account issues as: decrement A subscriber account and if the subscriber has money in his account.

MSC interrogates HLR about the B subscriber location. HLR “tells” in which VLR the B subscriber is and sends the address to the MSC that requested for it.

Speech connection path will set up towards the MSC/VLR where the B subscriber is presently located as follows:

- Sets up a speech connection towards RNC
- Delivers B subscriber ID to RNC and asks to page for the subscriber using that ID

In this stage, RNC sends a Paging Message to all the nodes B that it controls. Then, it carries a Paging Response from called MS back to MSC. It also allocates a Radio Channel through a node B with best available signal strength for called MS and performs Speech Coding when the call is established.

The attach procedure is similar to the one that was previously presented at the data set-up procedure, but the messages are exchanged between the MS and the MSC/VLR instead of MS and SGSN.

The next two figures illustrate how a MS can receive a circuit-switched call assuming that a packet-switched connection was already established.

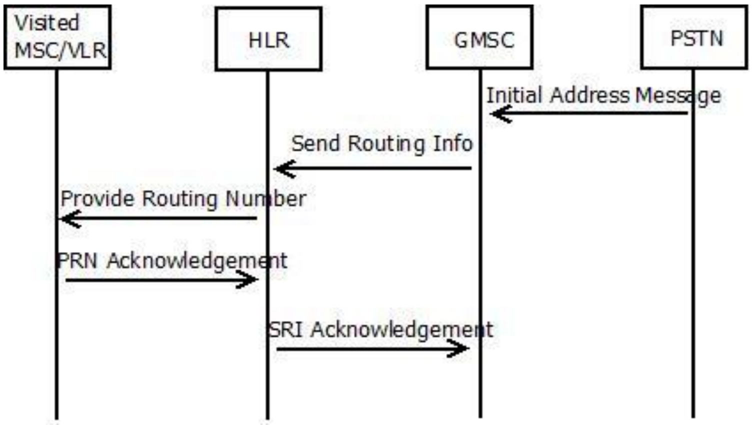

Figure 21: Retrieving Routing Information [6]

First, the PSTN contacts the GMSC in the home network of the mobile station with an ISUP initial address message. ISUP is part of SS7 and is used in the set up of calls. The GMSC then asks the HLR to send the routing information (SRI). The HLR asks the visited VLR to provide the roaming number so that the GMSC can forward the call. The visited VLR replies with the routing number to the HLR in the PRN acknowledgement and the HLR forwards the routing number to the GMSC in the SRI acknowledgement.

The GMSC then forwards the call to the routing number which is received by the visited MSC/VLR. The “Page UE” message is sent to SGSN over the Gs interface. The SGSN sends a page request to the RNC over the RANAP signaling connection with the Core Network Domain Indicator (CNDI) set to “Circuit Switched”. The RNC relays the paging request to the MS over an existing RRC connection. The MS responds with a page response message over that RRC connection and the RNC relays the page response to the MSC/VLR over the RANAP connection. The call setup message is sent to the MS with the bearer capability information and it responds with a call confirm message to the MSC/VLR. Finally, the MSC asks the RNC to allocate the traffic channel and the MS is notified about this allocated traffic channel [6].

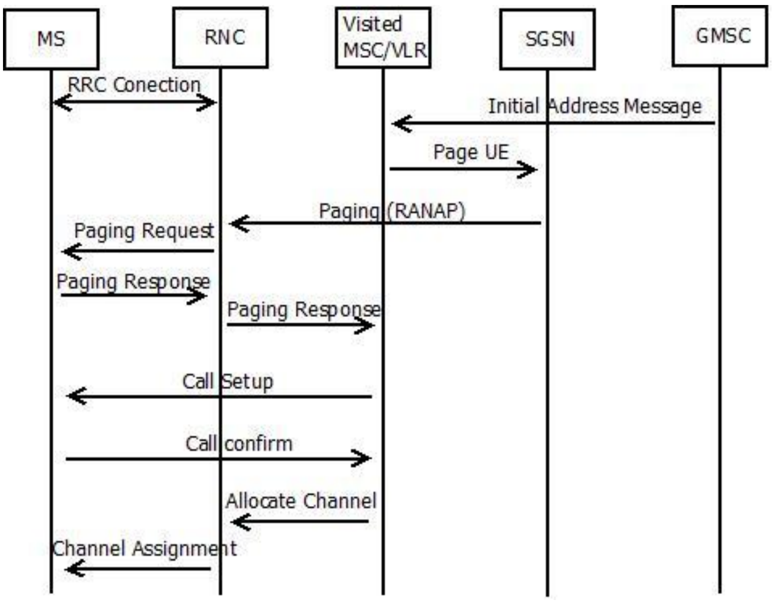

Figure 22: Received call final procedure [6]

3.1.3 Other considerations

After the analysis of the previous sub-chapters, is easy to understand the importance of MSC in Circuit switched domain and the importance of SGSN in Packet switched domain. They are the central NEs in the corresponding procedures and they participate in almost all the exchanged messages with other elements. The understanding of these procedures and messages will be very important in order to perceive some content that will be presented next.

To understand these previously presented procedures, it is important to have in mind the definition of the following terms:

Location Update ➔ A GSM or UMTS network, like all cellular networks, is a radio network of individual cells. Each small geographical area, within a uniquely identified location area is covered by a base station. The integration of the coverage of each of the base stations allows for a cellular network to provide radio coverage over a wider area; a group of base stations is named a location or routing area.

Whenever a mobile device moves from one location area to the next the location update procedure is what allows this information to reach the cellular network. The responsibility to detect location area codes belongs to mobiles and when a mobile finds that the location area code is different from its last update it performs another update; it does this by sending a location update request to the network, along with its previous location and its Temporary Mobile Subscriber Identity (TMSI).

The network may require a mobile to perform an IMSI attach or IMSI detach location update procedure whenever it is switched on or off. Each mobile is also required to report, on a regular basis, its location at a set time interval with the help of a periodic location update procedure.

TMSI ➔ The Temporary Mobile Subscriber Identity (TMSI) is the identity most commonly sent between the mobile and the network; VLR randomly assigns TMSI to every mobile in the area whenever it is switched on. The number needs to be updated each time the mobile moves to a new geographical area.

The mobile's TMSI can be changed by the network at any time and the global "international mobile subscriber identity" (IMSI) has to be sent to the network every time the data in the mobile becomes invalid for any given reason.

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IMSI ➔ Its purpose is to identify the user of a cellular network and it is a unique identification associated with all cellular networks. It is sent by the phone to the network stored as a 64 bit field; however it has other purposes like acquiring other details from the mobile device in the HLR or as locally copied in VLR. The IMSI is as rarely as possible and it is sent a randomly generated TMSI instead as a precaution measure to prevent "eavesdroppers" from identifying and tracking the subscriber on the radio interface.

The IMSI is used in any mobile network that interconnects with other networks and is provisioned in the SIM card.

Another concept that is very important in this subject is the **handover** concept. It is possible to define the handover as the process by which a session/connection is switched from one physical channel to another. This switch can happen due to various factors as movement of the mobile terminal, too much interference being produced by the terminal, or due to the necessity to balance the traffic load among adjacent cells. These factors have in common the fact that they depend on the physical channel quality. When the SNR (Signal-to-Noise Ratio) gets lower than a predefined threshold, a handover operation is required.

3.2 KPIs (Key Performance Indicators)

After the previous analysis, it is possible to conclude that the processes involved in establishing a call are complex and we can distinguish two different planes (control and data). To manage the network, we have to be aware of these planes and how they react in various situations. What happens and what plane causes problems when data traffic increases? And when we have a great number of subscribers in the network? In what way the handover interferes in the network? Why has the call failed? In order to answer these questions and understand the network management, the study of KPIs is mandatory.

All of these questions, along with the previously referred competition in the liberalized telecommunications market and customer requirements for more complex services led to the creation of KPIs. Basically, KPIs are metrics that evaluate process performance as indicators of quantitative management, and that measure progress towards the enterprise's goal. They can also be used to evaluate user's degree of satisfaction with the service provided.

KPI definitions include high level KPIs that are common across GSM, UMTS, LTE, etc., and KPIs that are related to specific network techniques [9].

The demand for a KPI may arrive from many sources. The KPIs can be suggested by standardization requirements, may come from Performance Management customer requirements, or from existing feature requirements.

KPIs are divided into categories. According to ITU-T, they are defined as follows:

KPI group	KPI Class	Description
Serveability	Accessibility	Ability of a service to be obtained within specified tolerances and other given conditions when requested by the user
	Retainability	Ability of a service to continue to be provided under given conditions for a requested period of time
	Integrity	The service quality of the provided service, once obtained
Availability	Reliability	Probability that an item can perform a required function under certain conditions for a defined time interval
	Maintainability	Probability that a given active maintenance action can be carried out under stated conditions in a stated time interval
	Utilization	Utilization of network resource such as throughput on a specific interface
	Mobility	Visualize the end-user movements

Table 4: KPI categories (based on [9])

According to the document “3GPP TS 32.410 version11.0.0 Release 11”, the fields that describe the KPI and should be part of its name are:

a) Long name(mandatory) : this field shall contain the long and descriptive name of the KPI

b) Description(mandatory) : shall contain the description of the KPI and information about its focus(network or user view)

c) Logical Formula definition (mandatory): the logical formula should describe what the KPI formula is in logical way. In that description is given a written textual format without any measurement or counter names.

d) Physical Formula definition(optional) : this field shall contain the formula description using the 3GPP defined counter names

e) Measurement names used for the KPI(optional)

f) KPI object(mandatory) : the object of the KPI is one or some of the following: UTRAN, GERAN, CS core, PS core, IMS

g) KPI category(mandatory): This field contains the classification of the KPI into one of the categories presented in table1

h) Unit of the KPI(mandatory): can be percentage, seconds, Erlang, etc.

i) Type of the KPI(mandatory): can be one of the following:

    MEAN - produced to reflect a mean measurement value based on a number of sample results

    RATIO – produced to reflect the percentage of a specific case occurrence to all the cases

    CUM – produced to reflect a cumulative measurement which is always increasing

j) Remark(optional) : this field is reserved for any additional information that is needed for the KPI definition

3.3 *Different Protocols*

A protocol is a set of rules that are used to manage communications. Protocols specify what types of data can be sent, how each type of message will be identified, what actions can or must be taken by participants in the conversation, etc. Some of those protocols are next presented because they play an important role in this cellular networks dynamics.

Ethernet

Ethernet is the most popular LAN technology in the world because it is an easy and relatively inexpensive way to provide high performance networking to all different types of computer equipment. It runs on a wide variety of physical media like coaxial cables and several types of fiber-optic cables.

Each piece of information transmitted on an Ethernet network is sent in something called a packet. A packet is simply a chunk of data enclosed in one or more wrappers that help to identify that data and route it to the correct destination. These wrappers consist of headers and/or trailers that are simply bits of data that are used for the previously mentioned purposes. The headers are added to the beginning of a packet, and trailers are added to the end of a packet [33].

Internet Protocol (IP)

IP is considered the primary protocol in the Internet layer of the Internet Protocol suite, and has the task of delivering packets from the source host to the destination host based on the IP addresses that are in the packet headers. For this purpose, IP defines packet structures that encapsulate the data to be delivered and also defines addressing methods that are used to label the datagram with source and destination information.

For the benefit of reducing network complexity, the error-correction intelligence in the network is mostly located in the end nodes of each data transmission. Routers in the transmission path forwards packets to the next known router that matches the routing prefix for the destination address.

As a consequence of this design, the Internet Protocol only provides best effort delivery and its service is considered unreliable because many different errors can occur. Data corruption, packet loss, duplication and out-of-order delivery are just some examples.

Asynchronous Transfer Mode (ATM)

ATM was created back in the late 1980s to help unify both telecommunications and computer networks that are using connections to send large amounts of data traffic through the same networks.

ATM is a connection-oriented, unreliable (does not acknowledge the receipt of calls sent), virtual circuit and packet switching technology. Unlike most connectionless networking protocols, ATM provides predictable and guaranteed quality of service. ATM technology includes:

- Scalable Performance: ATM can send data across a network quickly and accurately, regardless of the size of the network.
- ATM allows the accuracy and the speed of data transfer to be specified by the client. This feature distinguishes ATM from other high-speed LAN technologies.
- ATM supports integration of voice, video and data services on a single network.

ATM differs from Internet Protocol and Ethernet connections because it will not transfer any actual data until a reliable connection is made. It also uses fixed-size packets of data instead of variable-sized packets and frames.

4. Nokia Management tools

The rapid development of telecommunications networks and all of these previously presented dynamics, have turned network management and analysis into a large and complex task. In many cases, various technologies (like 2G, 3G, 4G and IP Multimedia) coexist in the same network, which leads to the requirement of several tools to deal with that complexity.

At the same time, determining the service quality and the impact of problems on subscribers has become increasingly important in a very competitive market as it is the case of telecommunications. For all these reasons, equipment manufacturers have put a special attention on the development and improvement of several tools to help in the network management tasks. In the context of the present work, the study of Nokia tools like NPM, NetAct and Traffica assumes, therefore, a major importance.

NPM is responsible for historical data and Traffica is responsible for real time data. NetAct is important because it acts like an intermediate between the network elements and NPM. These tools will be further analyzed in the next sub-sections.

Inserting these tools in Figure 1 scheme, we have:

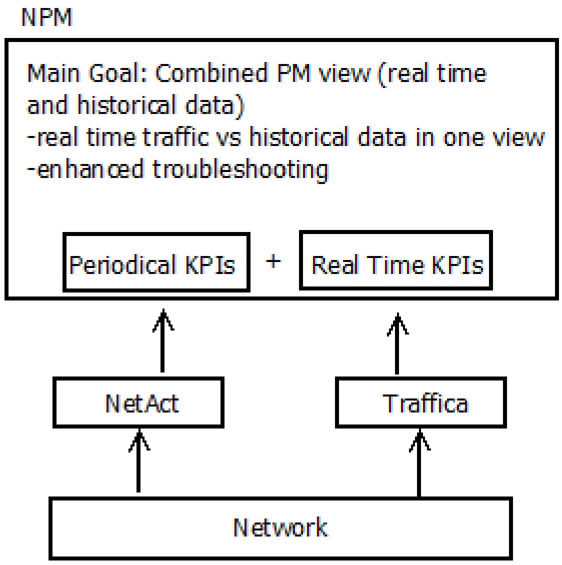


Figure 23: Nokia tools (drawn by the author)

4.1 NetAct

NetAct is Nokia's Operations Support System (OSS).

OSS are computer Systems used by telecommunications service providers to implement network management functionalities related to the operations, administration, maintenance, and provisioning of network systems and services.

Operations are concerned about keeping the network and its services running with minimum user impacts; administration deals with network control, maintenance deals with network and network elements (NE) upgrades and repair tasks, and provisioning is responsible for network resource configuration to support a given service requirement.

In short, OSS as a whole includes all the systems used to support the daily operations of the service provider [62].

The OSS architecture definitions were done by the ITU Telecommunication Standardization Sector in its TMN model, which has become the main reference for the telecommunication management solution providers.

In the next sub-section, more detailed information about this TMN model is presented.

The network management is continuously getting challenged and it is really important to provide a coherent and customer-focused view of this multidimensional combination of different networks, network elements and end user services.

NetAct comprises a common computing platform, an adaptation and mediation layer and an application layer.

Computing platform ➔ provides preconfigured third party hardware and software to support the operation of the upper layers. Third party software includes components for virtualization infrastructure.

Adaptation and mediation layer ➔ provides the interface through which data originating from network elements enters NetAct and can be handled by its applications. It also provides the application layer with services which are not specific to any network management operation, as access control and logging.

Application layer ➔ contains the applications for common management tasks, such as fault management, configuration management, performance management and network optimization. Applications are accessible via user workstations.

Next, it is possible to observe NetAct basic operation scheme:

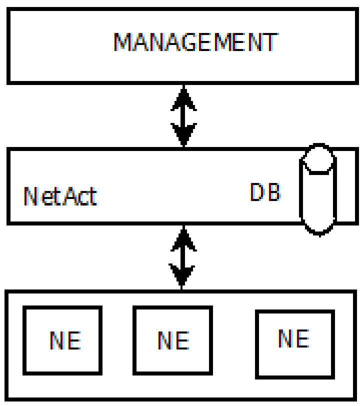


Figure 24 : Basic operation (drawn by the author)

In terms of hardware, NetAct consists of three main parts: servers, storage devices and network equipment, such as switches and routers. NetAct operating environment is fully virtualized.

In terms of software, NetAct is a three tiered architecture:

- Presentation tier ⇨ hosts client applications

- Business logic tier ⇨ hosts the business logic and data access specific for NetAct

- Data tier ⇨ hosts NetAct database and directory servers

Both Business logic tier and Data tier utilize virtual machines running on one or more host servers dedicated to NetAct.

This NetAct virtualization brings the following benefits, among others [35]:

- Reduced CAPEX and OPEX
- Hardware maintenance can be performed without business impact.
- Efficient disaster avoidance solutions by using shared redundancy resources
- All Hardware resources are in efficient use

With NetAct, the fault and configuration data can be processed into meaningful information about the network performance, which in turn can be posteriorly used by other Nokia tools.

Because of that, it is possible to conclude that the NetAct main function (at least in this dissertation context) is to turn data into meaningful information that should be further analyzed by other management tools like NPM. It is responsible for communicating with NEs, receiving information from those NEs, and then route it to an "upper layer" like NPM.

4.1.1 TMN (Telecommunications Management Network)

This model proposes a software framework and procedures to get flexible and reliable communications throughout heterogeneous operations systems and telecommunications networks.

TMN information architecture uses concepts from OSI Systems Management architecture and applies them in the context of telecommunications network management.

Thus, the concept of the TMN model is to provide an organized architecture with standardized interfaces, capable of interconnect various OS (Operating System) and/or NE for exchange management information by the network operator.

The figure below shows the relation between the TMN network and the telecommunications network that is managed by it.

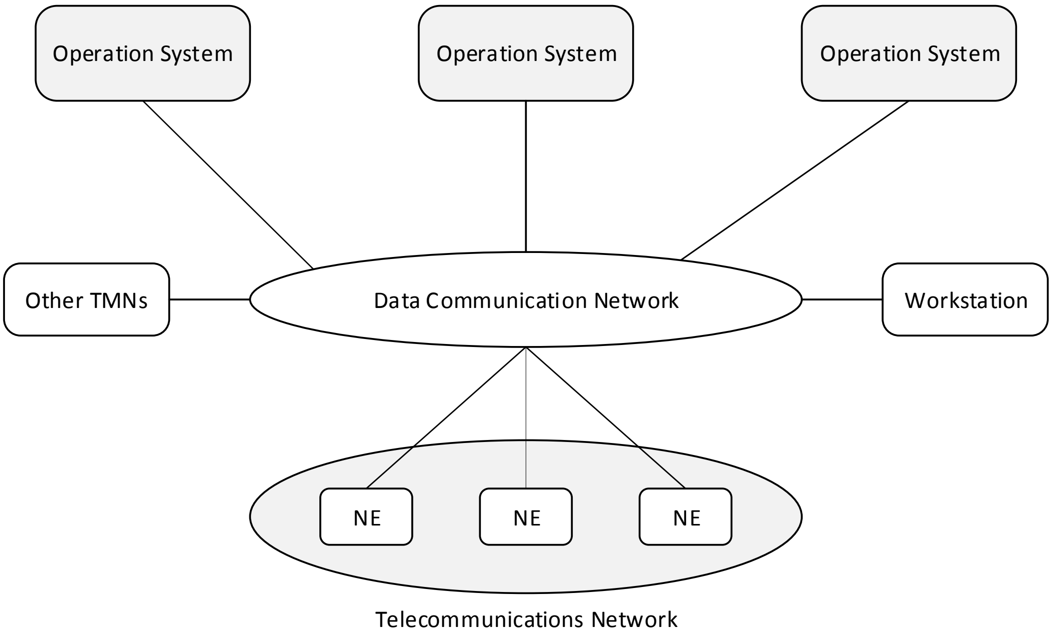


Figure 25: Relation between TMN and telecommunications network [15]

The logical function blocks of the TMN are shown in the next figure:

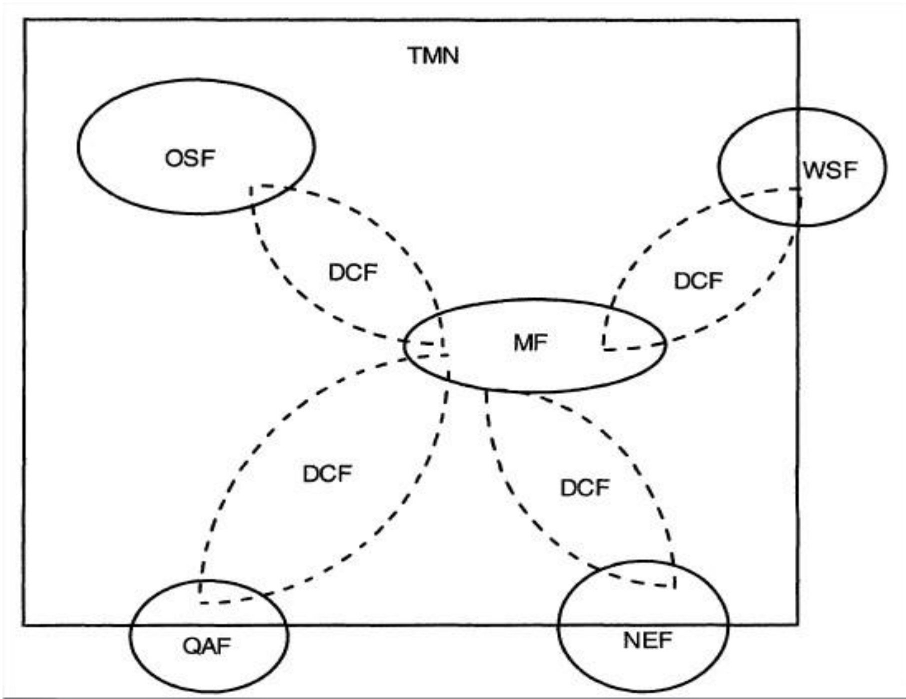


Figure 26: TMN logical functions block [49]

In this figure, the solid circles are part of the TMN and the dotted circles represent a requirement that is not strictly a TMN logical function block.

According to [49]:

OSF – Operations System Function ➔ can be seen as the telecommunication manager. Represents the processes associated with management of the telecommunications network. Includes the following activities: obtaining management information such as alarm status of managed entity, performing the required information processing activities on the retrieved management information, and directing the managed entities to take appropriate corrective actions

DCF – Data Communication Function ➔ includes functions that address routing, relaying and error-free transmission of octet stream

QAF – Q adapter Function ➔ is a gateway to bridge the non-TMN systems to TMN systems.

NEF – Network Element Function ➔ is partially located in the TMN. Aspects of NEF such as support for call processing are outside the TMN and are part of the telecommunication network. Communicates with the TMN with the purpose of be monitored, i.e. the NEF includes the telecommunication functions that need to be managed.

MF – Mediation Function ➔ performs the necessary functions to mediate the information exchange between two other function blocks. For the current application of TMN, is between the OSF and NEF. It may include capabilities to store, filter and adapt data.

WSF – Workstation Function ➔ this block is able to translate and present TMN-defined management information to a human user and to translate from user requests to representations used by TMN entities.

Information Architecture

TMN´s information architecture uses an object oriented approach and is based on OSI's Management Information Model. According to this model, the management view is described in terms of:

- Attributes that are properties or characteristics of the object
- Operations which are performed upon the object
- Behavior which is exhibited in response to operations
- Notifications which are emitted by the object

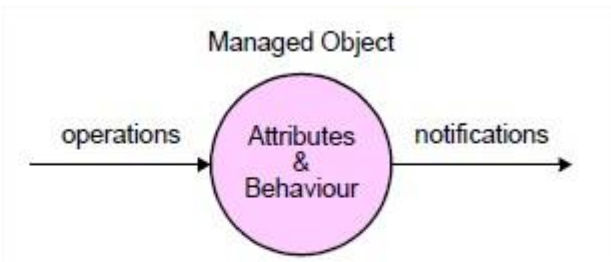


Figure 27: TMN managed object [49]

Managed object concept refers to an abstract representation of a network resource, which can be either a physical or logical entity, in a network managed by NetAct. Examples of different types of managed objects are base stations, gateways, servers and routers.

The information managed by an OSF may be separated into various levels/layers of abstractions, as we can see in the next figure. This decomposition is useful to deal with the complexity of management and its associated information. Each layer is responsible for providing the appropriate FCAPS functionality according to the layer definition. Each layer communicates with the layer above and below it.

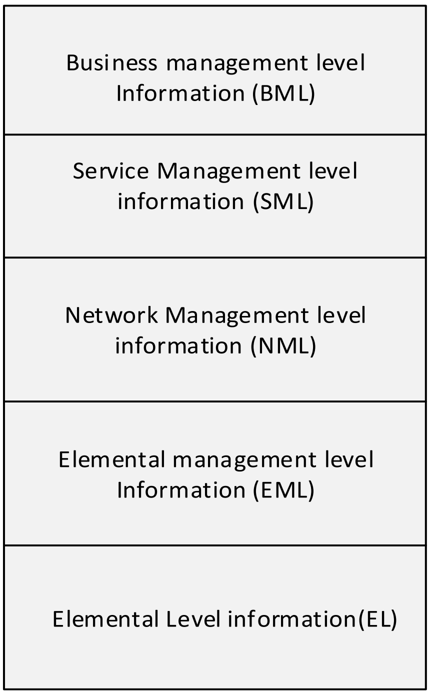


Figure 28: TMN levels of abstraction [49]

<u>Element Management Layer</u> (EML)

This layer deals with vendor specific management functions and hides these functions from the layer above that is the Network Management Layer.

Functions performed at this layer:

- Detection of equipment errors
- Measurement of power consumption
- Measurement of temperature of the equipment
- Measurement of resources that are being used
- Logging of statistical data
- Updating firmware

Network Management Layer (NML)

This layer has the responsibility of managing the functions related to the interaction between multiple pieces of equipment.

Functions performed at this layer:

- Creation of the complete network view
- Creation of dedicated paths through the network to support the QoS demands of end users
- Modification of routing tables
- Monitoring of link utilization
- Optimizing network performance
- Detection of faults

The OSFs(Operational System Functions) at the Network Management layer use the vendor independent management information that is provided by the OSFs in the Element Level information layer(EL).

Service Management Layer (SML)

This layer is concerned about managing the aspects that may be directly observed by the users of the telecommunications network, either end users or other service providers. This layer is built upon the management information that is provided by the Network Management layer, but doesn't see the internal structure of the network.

Functions performed at this layer:

- QoS management (delays, losses, etc.)
- Accounting
- Addition and removal of users
- Address assignment
- Maintenance of group addresses

Business Management Layer (BML)

This layer is responsible for the management of the whole enterprise. Business management can be better related to strategical and tactical management, instead of operational management, like the other management layers of TMN.

Main functions of this layer:

- Support of the decision process for the optimal investment and use of new resources
- Support the management of Operation, Administration and Maintenance budget
- Maintain aggregate data about the total enterprise

4.1.1.1 FCAPS Model

FCAPS ➢ Fault, Configuration, Accounting, Performance and Security

The definition and the main functions of these elements are (according to [16]):

- **Fault management**

Recognizing a problem in the telecommunication network is the first step in Fault Management. In order to have an effective fault management is required to have detection, recognition, isolation, correction and log of faults that occurs in the network.

- **Configuration management**

It is concerned with monitoring network elements and their configuration. It has various functions, such as identify, exercise control over, collect data from, and provide configuration data to the various hardware and software versions of network elements.

- **Accounting Management**

This functional area is concerned about the collection of user usage statistics. These statistics can be controlled and used to improve the fairness of the network access and thus, minimize network problems. Next, we can see some of its functions:

- Usage measurement
- Tariffing and pricing: used to determine the amount of payment for service usage.
- Collection and finance: receive payments; inform the user of payment dates, administering customer accounts.
- Enterprise control: supports the enterprise financial responsibilities.

- **Performance Management**

Evaluate and report about the behavior of telecommunications equipment and the effectiveness of the network or network element (NE). Gathers and analyzes statistical data with the purpose of monitoring and correcting the behavior and effectiveness of the network, NE and/or other equipment. Moreover, assists in planning, provision and maintenance and quality measurement. The next functions are included in the performance management functional area:

- Performance quality assurance: includes quality measurements such as performance goals.

- Performance monitoring: responsible for the continuous collection of data concerning the network element performance.

- Performance management control: includes setting thresholds and data analysis algorithms. It has no effect on the managed network.

- Performance analysis: additional processing and analysis to the collected performance records

- **Security management**

  Security management consists of two main functions:

  - Security services for communications such as authentication, access control, data confidentiality, data integrity, etc. In addition, a set of security mechanisms are defined to be applicable to any communication, such as, event detection, security audit-trail management and security recovery.
  - Security event detection and reporting activities that may reside in a security violation (unauthorized user, physical tampering with equipment).

4.2 NPM (Nokia Performance Manager)

4.2.1 Introduction

The Performance Management System needs to handle the growing flood and complexity of data from today´s mobile broadband networks. It collects a vast amount of data across the network and interprets it to present an overview of network performance. Thus, the Performance Management system plays an important role in the daily operations of a telecom network. To be effective, it is necessary to centralize the data from various data sources into one place, where it can be brought together to give a unified view of the network.

In general, the elements that are part of management tools are the following (based on [10]):

Network Elements

These are the telecom equipments that are intended to be monitored and from which the data is retrieved (MSC, MGW, SGSN, etc.).

Element Manager (EM)

It is in charge of the interaction with the NEs, and its major function is the extraction of the NE performance and fault information. After that, it provides the information to the Reporting Tool.

Reporting Tool

It is in charge of presenting to the user the pre-defined KPIs and the associated reports (a set of organized PIs and KPIs). It gets in contact with the EM and retrieves the necessary data. Such data is then uploaded to the Reporting Database and modulated based on NE specific metadata. After the required modulation, the data is presented to the user via the GUI (Graphical User Interface) module. Typically, the outputs are predefined reports that can briefly be described as a logical set of PIs and KPIs with drill-in capabilities.

This tool may also be connected to other data systems, and data can be exchanged using XLS, XML and HMTL. The access to the Database can be achieved by using a SQL interface, for an example.

The next figure illustrates these referred elements:

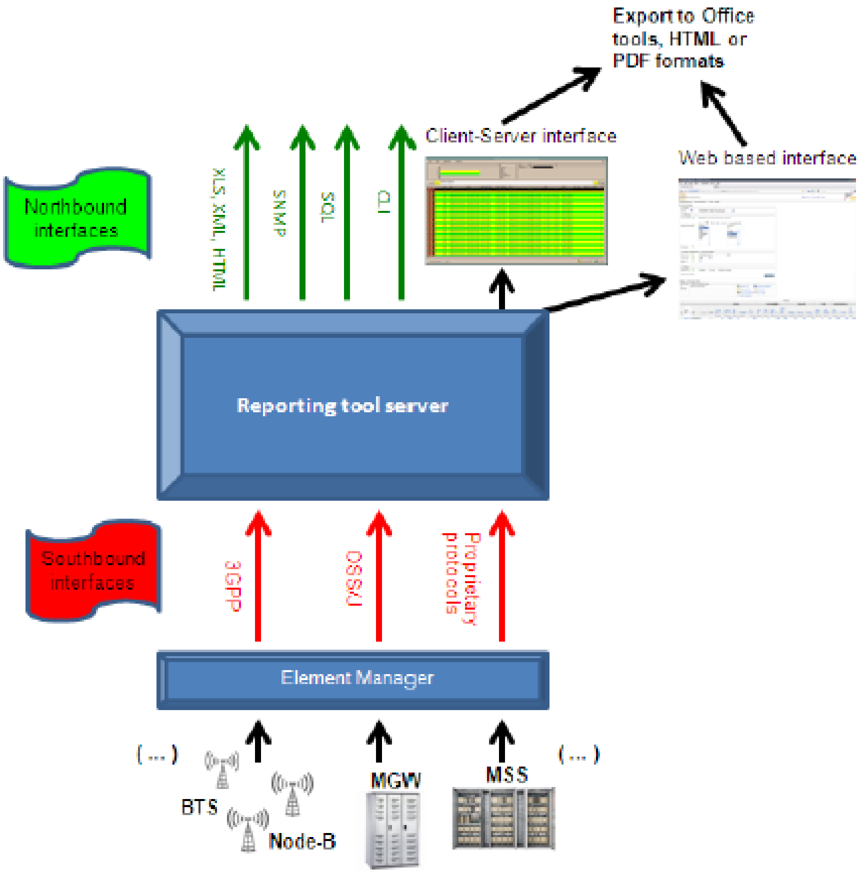


Figure 29: Reporting Tool Interfaces [10]

In this specific case, NetAct can be considered the Element Manager, and NPM can be considered the Reporting Tool.

4.2.2 NPM the tool

So, NPM acts as the centralized data warehousing solution where applications can find a purified view of the network's performance and where reports can be defined on the fly using advanced tool sets [17].

In addition to the collection and storage of PM data from the entire network, other relevant data such as configuration, fault statistics and service relevant information are stored in this solution.

For most Performance Analysis tasks it is neither necessary nor advisable to store raw data for long periods of time. Instead, the data must be aggregated for more efficient analysis.NPM provides long term storage (from months to several years) for raw and aggregated network performance historical data, ready to be used in the calculation of KPIs and in the production of meaningful reports.

NPM is also a multi-vendor and multi-technology system powered by NetAct platform and covering, for example, support for 2G, 3G, LTE, transport, core, fixed and IP network domains.

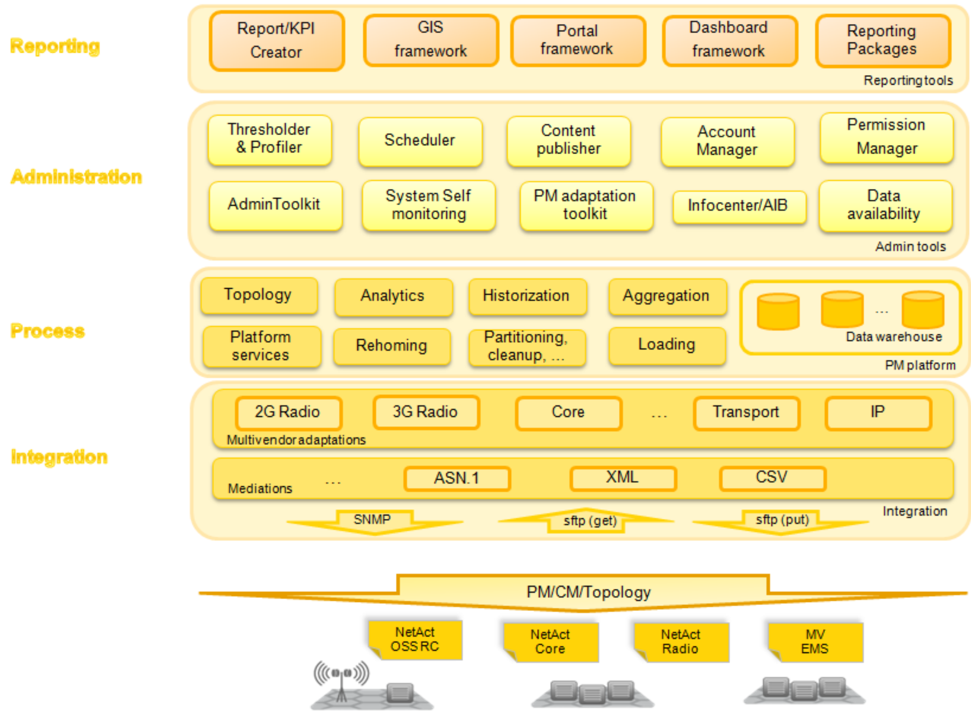


Figure 30: NPM high-level architecture [17]

There are four main components in NPM platform, as it is illustrated in the next figure:

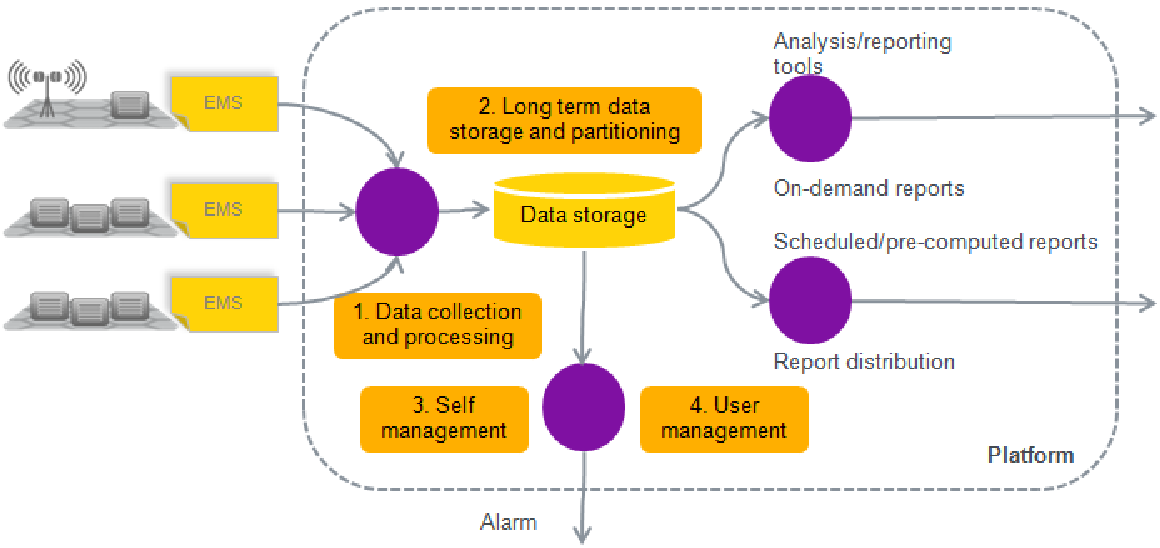


Figure 31: NPM Platform components [17]

1. Data Collection and processing

Data is collected from multiple systems and placed in one centralized data warehouse. A data warehouse is a database that is designed to help in querying and analyzing data, rather than performing transaction processing. As part of the collection process, the data may need to be processed. Aggregation is typically done into object and time dimensions so that operators can see what happened in different parts of the network in a given time interval.

2. Long term data storage and partitioning

It is possible to scale the PM database hardware and configure storage time for raw and aggregated data to fit the requirements of any network size.

Nokia Performance Manager uses an Oracle database solution. It has been found that as data volumes increase, the multi-dimensional databases do not scale satisfactorily, so Oracle is the best choice.

An important data storage feature implemented by NPM is the partitioning of large database tables, which leads to faster searches on those tables.

The Hadoop and Storm interfaces assume huge importance on those partitioning processes.

Apache Hadoop is an open source software framework for storage and large scale processing of data-sets on clusters of commodity hardware.

Here is how Apache formally describes it [20]:

“The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models. It is designed to scale up from single servers to thousands of machines, each offering local computation and storage. Rather than rely on hardware to deliver high availability, the library itself is designed to detect and handle failures at the application layer, so delivering a highly available service on top of a cluster of computers, each of which may be prone to failures.”

In other words, it is designed to be robust, so your applications will continue to run even when individual servers or clusters fail and it is also designed to be efficient because it doesn´t require your applications to shuttle huge volumes of data across the network. Besides this, Hadoop is almost completely modular, which means that you can swap out almost any of its components for a different software tool. With all of these features, Hadoop is incredibly flexible as well as robust and efficient.

In a “normal” relational database, data is found and analyzed using queries, based on the industry standard SQL. Although Hadoop stores data and you can pull data out of it, it is not really a database and that is why there are no queries involved. Hadoop is more like a data warehousing system so it needs a system to actually process the data.

Hadoop can´t manage real time data so another system is needed - Apache Storm. The Real time issue is important because is able to provide better end-use experience and operational intelligence like low latency analysis and real time dashboards.

Apache Storm is a free and open source distributed real time computing system. Storm is capable of processing unbounded streams of data, doing for real time processing what Hadoop did for batch processing. Storm is simple and can be used with any programming language.

3. Self Management

This functionality includes OS database resources supervision and database clean up. Alarms on specific events can be triggered and sent to an external system. The alarming functionality is important because it helps to take appropriate actions timely.

Additionally, the reporting tools can be used to see how the different parts of the PM pipe perform and this information can help in planning hardware upgrades or changes in the aggregation strategy.

4. User Management

For each separate network domain, NPM offers technology modules that include the following content:

- raw data : all counters that are sent from the NE are available for reports
- aggregation of data : The data is aggregated, for example, in time and in object levels and stored in the database
- Busy hours for different measurements calculated for daily and weekly peak values or any other busy hour defined for a given technology integration

The next figure illustrates NPM operating mode:

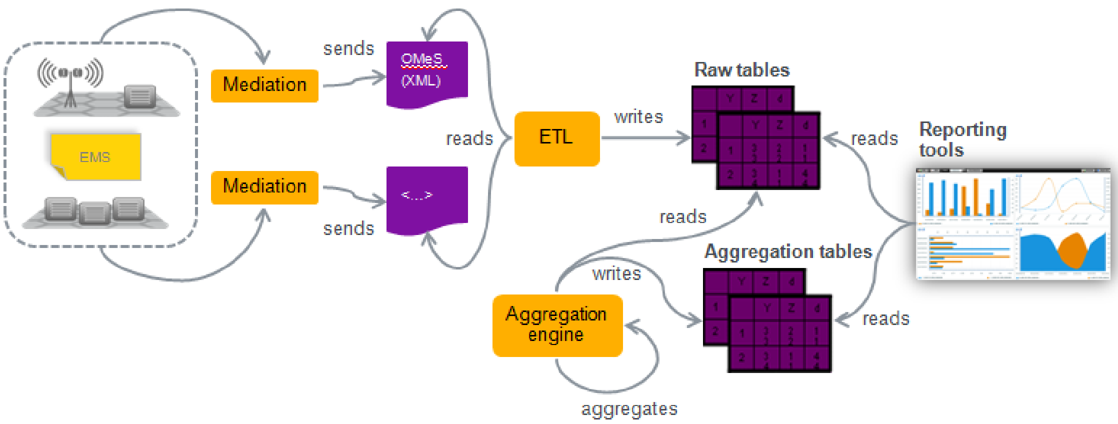


Figure 32: NPM Operation [17]

As it was previously written, with NPM, the telecom operators can view and analyze the network performance, fault and configuration data coming from different sources. Through the mediation process, “disorganized” data is turned into meaningful information and is written in Raw tables. Then, that information may be aggregated and visualized in graphical and textual reports. KPIs are the most important indicators of the networks’ performance and KPI reports allow the operator to detect the first signs of performance degradation, prevent the development of critical network problems, troubleshoot specific elements and analyze performance trends.

The mediation process will be focused in another section of this dissertation.

This tool provides a wide range of functionalities and reporting tools that are targeted for all user groups of a performance management system. These functionalities and tools are described next.

The following figure describes the main components of the main window layout of NPM.

Figure 33: NPM main window layout [17]

Generally, this main window has the following four components:

Main menu bar

- This menu bar is located at the top of the main window and provides access to system wide functionalities or tools

Context specific menu bar

- Is located at the top of every page and provides access to the main actions of that page

Navigation tree

- Allows the selection, view and edition of different objects, for example.

Report frame

- This is where the report, charts or other data objects can be viewed. It has some reporting functionalities like: reporting documentation, including KPI formulas; export to excel and CSV (Comma Separated Values) files; advanced filtering; drills and KPI search.

4.2.3 Useful functionalities

The most useful functionalities for this particular work are the following:

Advanced Filtering

These functionalities provide powerful tools to quickly calculate runtime peak busy hours, for an example, and other useful filtering options.

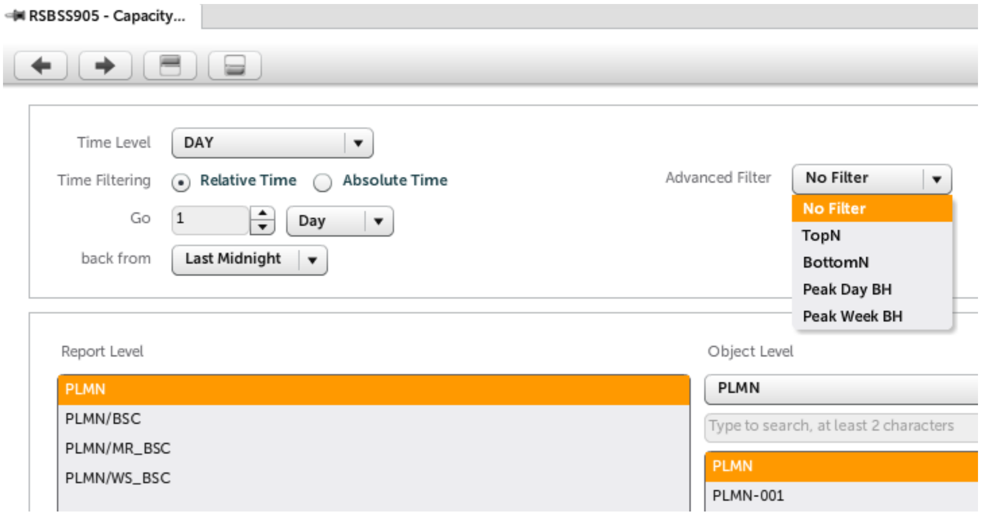


Figure 34: Advanced Filtering options [17]

Drills

It is possible to drill on the report artifacts in both table and chart views. Several options are available as illustrated in the next figure:

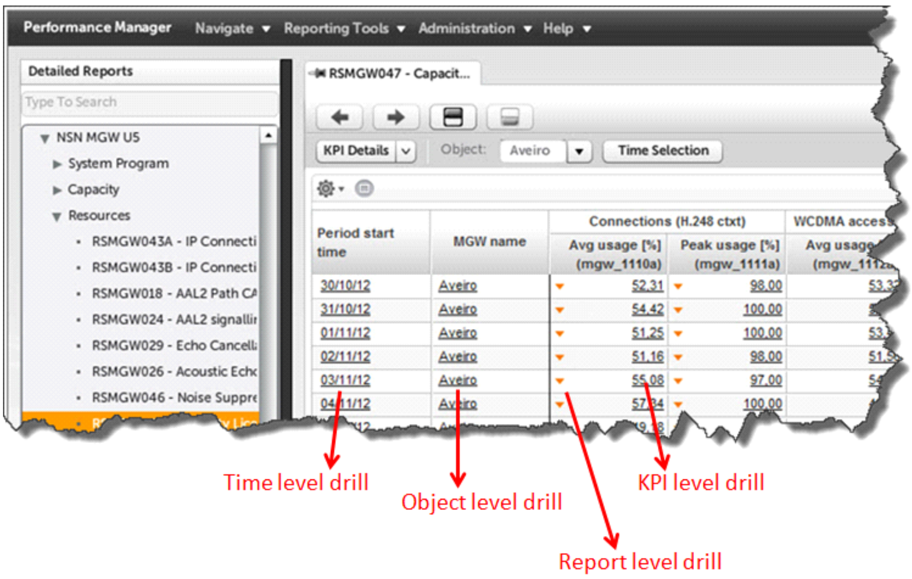


Figure 35: Report Drill options [17]

The first one allows the user to choose the level of information to be shown and to apply several filters to existent data.

The Drill functionality is probably the most important functionality because it allows drilling in many levels like time, object and KPIs. These drill options allow multiple analysis and offer a much more complete view of the situation.

As an example, time level drill allows the user to drill from day to hour, object level drill allows the user to drill from PLMN to MSC and KPI drill may show the counters that constitute the KPI. The report level drill can be configured to drill into the wanted information.

Besides these, NPM has other functionalities like:

Reporting documentation

This functionality gives the possibility to see report and KPI related information.

Export to Excel

This functionality allows the user to export all the report data to a Microsoft Excel spreadsheet file. That file contains one sheet with the report details including the report KPIs description and formulas and another sheet with the KPI values table. It also contains the SQL statements used for generating the report. This is important because provides the report user with clear definitions on what is behind the KPI formula.

KPI search

When displaying reports on a table view, it is possible to look up specific KPIs in the column headers. This is especially useful when managing large reports with huge number of table KPIs and provides a quick and easy way of finding specific KPIs within a report.

All of these features and functionalities contribute to NPM operation and they make it a very complete tool with the ability to present a big variety of information. However, it can´t present minute based (real time) information, and that is why the next presented tool is needed.

4.3 Traffica

4.3.1 Introduction

Traffica is a tool designed to help perform the previously mentioned network management tasks. This tool is able to show the network traffic and service delivery capability in real time. It also stores records for each call attempt, SMS delivery and data session into a database for further use in troubleshooting and customer care.

Traffica provides subscriber-specific information from successful and unsuccessful traffic events, such as subscriber Attach and PDP context activation, voice and data calls, SMS deliveries as well as radio network related events. Visibility to roamers and the type of mobile devices used is also provided.

Traffica complements other Nokia products with a scalable solution and integration ability.

Summarizing Traffica key functions:

- easily identify the root cause of technical problems and take actions to fix them

- real-time, simplified customer-specific data to help solve problems

- solve service configuration issues instantly and keep the services rolling

More specifically, Traffica allows the operator to see the customer activity in real time and in each cell.

- see how services are being used in real time

-see how network resources are really being used

-quickly spot customers who are trying to use services without success

-discover and solve problems as soon as they are experienced

-identify which devices are most popular and which cause most problems

In order to get an idea about this tool's importance, have in mind that there are thousands of cells with millions of calls per day that create thousands of events per second, and Traffica allows us to see it all in one view.

Basically, it is possible to define Traffica operation in 4 steps [44]:

1- Follow Network performance indicators
   -Spot Service performance degradation in real time
   -Detect sites carrying no Traffic at all
   -Setup thresholds alarms to automate the detection

2- Analyze problem severity and location
   -Use failure graphs and check if the problem is limited to certain NEs and cells
   -Check if there is still some traffic in NE or cell and if the fault is in a priority site

3- Troubleshoot the problem with linked graphs
   -Use drill down graphs to isolate the problem further down in topology
   -Study clear codes for determining the actual fault

4- Fault(s) and problem(s) clearly identified

Regarding MSS and MGW, there are some differences in Traffica that are worth pointing out:

Traffica for MSS (focus on control plane) ➔ provides real time visibility of live traffic, subscriber activities and mobile management, either throughout the whole network or down to the cell level. Being connected directly to the MSS provides instant visibility to basic QoS factors, such as call setup times and success rates. Mobility management quality indicators such as location updates, handover success rates and handover times are also supported. It can also provide a wide range of other information like [45]:

- How much subscribers are using the services, at what time, from where in the network and what problems they experience
- Call completion analysis and mobility management qualities
- Call details, SMS and other activities for each subscriber
- Use of different mobiles and problems per mobile type
- Activity of user groups, of roamers vs home subscribers, corporate customers, etc
- Roaming and traffic destination analysis

Traffica for MGW (focus on user plane) ➔ identify interface failures, detect voice quality problems and monitor network elements and used paths degrading voice quality. It also allows evaluation of the traffic behavior in the MGWs and, being at the center of the user plane, it also knows the situation in external networks such as radio access and IP backbone.

In the next figure, we can see Traffica layered architecture and the different components that are part of that architecture.

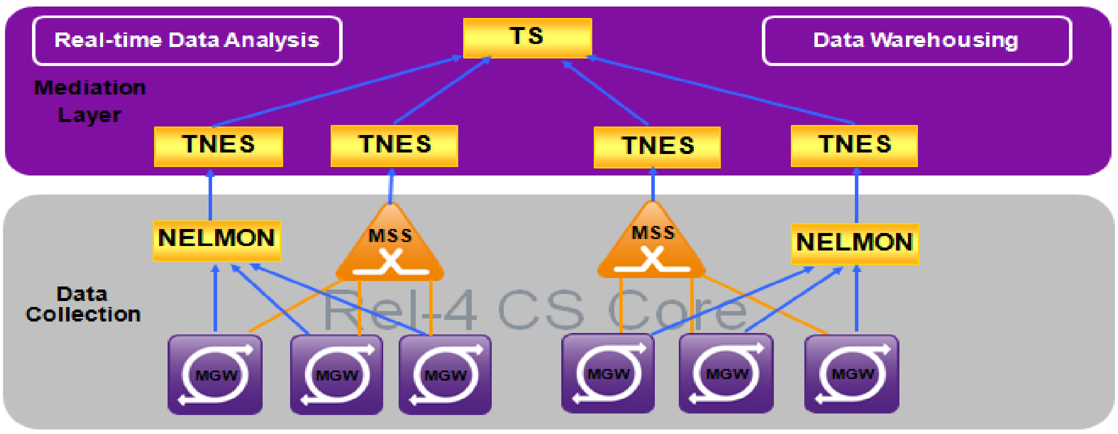


Figure 36: Traffica Layered architecture [12]

As it is possible to observe, the main Traffica components are the following:

TS (Traffica Server) ➔ is a central point in Traffica system and is connected to all TNESs. It acts as a server for Traffica clients and it also handles system administration tasks.

TNES (Traffica Network Element Server) ➔ is the Traffica that is connected to an NE (Network Element). TNES receive the RTT reports and those reports are stored into the Traffica database. Note that 'RTT Reports' is a term used for the Real Time Traffic reports that are generated by NEs and issued to the connected TNES. This term also includes redirected RTT Reports that are transferred from a TNES to TS [47]. TNES have online data storage for post processed counter data that is called CCMA (Clear Code Matrix).

TNES is network element-specific.

NELMON ➔ Nelmon is an external Linux-based server application developed by Nokia for collecting user plane quality monitoring data in real time from MGW [42]. It supplements existing MGW measurements by adding more granularity and enabling real time monitoring. NELMON server application stores the data into database and forwards it to Traffica in real-time.

Another point of view about Traffica architecture and applications is presented next. As it is possible to observe, Traffica allows real time graphs and alarms that can play a very important role in network management. For this dissertation in particular, CCMA Export seems to be an extremely interesting application and it will be deeper analyzed over the next sections.

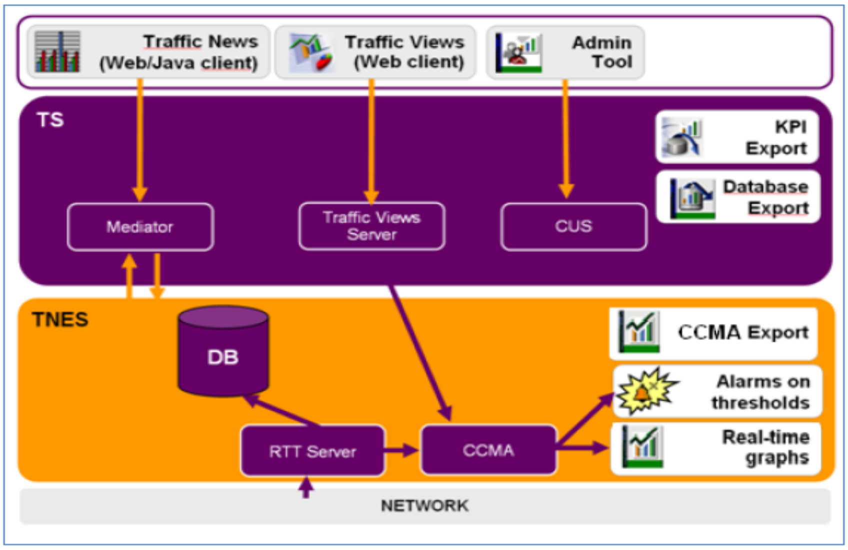


Figure 37: Traffica architecture and applications [12]

Traffica system can be deployed in basic solution and dual level solution mode. The basic solution is selected if there are a maximum of 100 TNESs and in this solution, all TNESs are connected to one TS. In other cases, a dual level solution should be selected. In this solution, there are upper level TS that are connected to lower level TS. These lower levels are connected to TNESs.

4.3.2 Some Traffica applications

Real-time Traffic Server (RTT Server)

End users can use RTT server for viewing real time graphs and alarms. In addition, if it is running in TS, it can be used for administering the Traffica System. Besides this, it also carries the following functions: collects RTT reports from an NE; stores RTT reports into the database; Updates CCMA counters and local graphs based on those counters; generates alarms

Traffic News

It is designed for the offline analysis of traffic data.
It allows making queries in the database and defining conditions for the search.

Traffic Views (optional)

Traffic Views is a client solution for searching, viewing and analyzing Traffica real time graphs that provide visibility to the entire Traffica network and the traffic from the end user point of view.

Database Export (optional)

Traffica Database Export is a tool for exporting raw data from TNES databases to external systems where the data can be post processed and further analyzed. This makes possible to integrate Traffica with other customer systems like fraud detection system or PM tools, for example.

Traffic Simulator

Is an application that is designed for rerunning the collected network traffic and its main purposes are: repeating failure situations in the network and visualizing them, because it helps to create alarms with correct thresholds; demonstrations and training, and it can be used whenever a real NE connection is not possible.

4.3.3 Traffica Basic Functions

Data Collecting and Storing

Traffica receives records for each call attempt, SMS delivery attempt, etc. It is a huge amount of data. These data is saved in database and at the same time is analyzed in the real time KPI engine of Traffica. The calculated KPI and PI data is visualized in Traffica real time graphs. In addition to these applications, this information is considered valuable by other systems and it is possible to export it.

Data Handling

Traffica TNES collects RTT reports (real Time Traffic reports) received from switches or data collectors in real time, or CDRs in almost real time. It then extracts the defined data, stores it in the database and updates the Clear Code Matrix (CCMA, counter and KPI tree) on the basis of the received data contents. Offline, RTT reports or CDRs are stored in the Traffica database. The amount of data that can be kept in the database is variable and typically the storage time is from one to two weeks.

Online, the CCMA defines the conditions to analyze data. Those conditions specify which data is to be collected and which counter is to be stored. Each RTT report updates each branch of the CCMA tree in real time. The data in the CCMA is stored in the Traffica memory (RAM).

Real time graphs and alarms are always based on CCMA counters and are updated as the CCMA counter values are updated.

Data Export

Traffica **database export** is a tool that can be used to export raw data from TNES databases (excluding today's data) to any external system. It makes it possible to integrate Traffica to other customer system like PM tools, for an example.

The task of Traffica **CCMA export** is to export the calculated values of pre-defined CCMA counters/KPIs in csv file format to external FTP server.

Therefore, Traffica can export KPI/PI/CCMA to other PM databases.

CCMA Export configuration consists of RTT Server CCMA configuration, CCMA Export Configuration File (Conf File) and CCMA Export Initialization File (Ini File).

Most Traffica default CCMA time classes do not support exporting data from them. To be able to export a counter or a vector, they need to have an export label defined for them.

The Conf File is a checksum protected file and it defines the time class or individual CCMA paths to be exported. This file also contains default values for some parameters like maximum disk space usage, export directory, etc. This file can´t be modified in runtime environment, but can list which parameters can be overridden in that runtime environment. This is done with CCMA Export Initialization File which is an optional file.

These files play a very important role in this study and they will be studied in more detail in the next sub-section.

CCMA Export Configuration is always specific to one CCMA time class and if there is data related to more than one CCMA time class, a new CCMA Export Configuration needs to be created for each of them separately.

The next figure summarizes these basic functions and illustrates Traffica data flow:

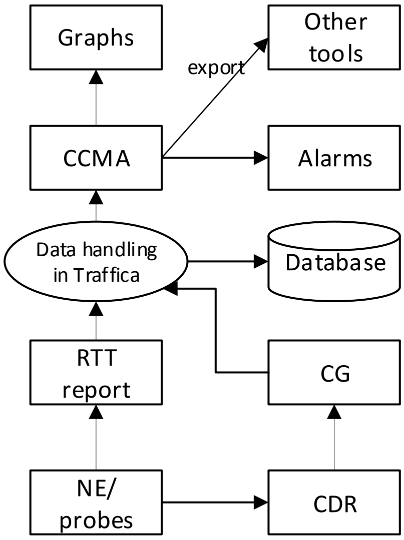


Figure 38: Traffica Data flow (drawn by the author based on [46])

4.3.4 CCMA Export Files (More detailed)

As CCMA Export represents a possible way to export data from Traffica to NPM, the study of the files that are part of this procedure is very important.

4.3.4.1 CCMA Export Configuration File

This file, also known as Conf File, defines the time class and optionally specific CCMA paths, which are to be exported. Each Conf File relates to one time class and there can be multiple Conf Files in each TNES. This file needs to exist in the active workspace directory of the TNES.

RTT Server polls Conf Files from workspace Directory at 10 second intervals. If files have been added, modified or removed, CCMA Export is re-configured according to the changes.

- Naming

Conf File name syntax is TrafCCMAE_<DataFilePrefix>.extconf, where <DataFilePrefix> is found from each Data File name and Control File name related to this Conf File. File name needs to be unique.

- Structure

This file is constituted by a section header, a list of parameters and a checksum.
The first section header in a Conf File is [Configuration].
The list of parameters is presented in the following table:

Parameter name	Presence	Description
`export-name`	Mandatory	Defines name of the export. Value needs to be same unique string as <DataFilePrefix> in the filename.
`time-class`	Mandatory	Defines the CCMA time class where exported counters and vectors are defined. There can be only one time class defined. If data is exported from multiple time classes, own Conf Files are required for each time class. String needs to be within quotation marks (“”).
`ccma-path`	Optional	Optional list of specific ccma paths which are wanted to be exported instead of everything in the time class containing export labels. There can be multiple ccma-path parameters, each counter on its own ccma-path parameter. Path needs to be within quotation marks (“”). Time class name is omitted from the ccma path and it begins with ‘\’.
`Exportdir`	Optional	Path of the directory where the Data and Control Files are written. String needs to be within quotation marks (“”). By default “C:\Traffica\Reports\TrafCcmaExport”
`License`	Mandatory	Name of license entry that is checked in Traffica. Maximum length for license entry name is 28 characters. Allowed characters are A-Z, 0-9 and '_'. If the license entry does not exist or has expired, Data Files are not generated. When a valid license entry is provided, Data Files are generated after the next file update.

`Maxsize`	Mandatory	Defines maximum size for one Data File. Value is given in megabytes. If `maxsize` is exceeded, a new Data File is started immediately. Note that if both `interval` and `maxsize` are defined, file is generated always at the end of the interval and possibly in the middle of the interval if `maxsize` becomes too big. The allowed range for `maxsize` is 0.1 – 16777215 megabytes, but the value cannot be bigger than 0,7*`maxdiskspace`, which is also the default value for `maxsize`.
`Maxdiskspace`	Optional	Amount of disk space what Data Files related to this export configuration can take from TNES local disk. Value is given in megabytes. The minimum value is one megabyte, and there is no maximum value. By default `maxdiskspace` is 100 MB. If all reserved disk space is used, the oldest Data Files related to this export are permanently deleted when new ones are written.
`Blocksize`	Optional	The size of the data block that is written to the Data File in one write operation. This parameter can be used in optimizing Traffica performance. The parameter has an effect on Traffica disk I/O and memory consumption. The allowed range is 0.01 – 50 MB and the default value is 2 MB.
`UTCTimestampInFilename`	Optional	UTC Timestamp of the time class reset in ctr and dat file names is included in addition to the timestamp in TNES local time. Possible values are ‘yes’ and ‘no’, default value is ‘no’.
`Doubletypeoff`	Optional	Normally move and sum type values are exported as DOUBLE type. Some parsers do not support

		DOUBLE, with this setting it's possible to export those values as UINT32 instead of DOUBLE. Possible values are 'yes' and 'no', default value is 'no'.
exportvectoritemcount	Optional	CCMA vector sizes can be exported out via CCMA Export. If exportvectoritemcount is on, additional field called VECTOR_ITEM_COUNT is included in the export files. CCMA vector item count can be subscribed from all vectors or from selected vectors. See more information about vector item count export below. Possible values are 'yes' and 'no', default value is 'no'.

Table 5: Conf File Parameters [25]

[Overridables] section is an optional section and lists the parameters that can be over ridden in the Ini File.

Checksum is a string in the last line of the Conf File and is calculated based on the content of the file with a specific tool. It is used to check the content of the file that has not been modified after the checksum has been generated.

Example

```
;*******************************************************************
;
;   Traffica
;   Configuration File: TrafCCMAE_TRAF_RNC_RTM.extconf
;   Version: 5,4,319,0
;
;   NOTE! Editing or removing this file is forbidden.
;   Editing or removing disables Traffica operations.
;
;   Copyright (C) Nokia Siemens Networks 2012.
;   All rights reserved.
;
;*******************************************************************
```

```
[Configuration]
export-name=TRAF_RNC_RTM
time-class="TRAF RNC RTM, 1 Min"
exportdir="C:\Traffica\Reports\TrafCcmaExport\"
license=CCMA_EXPORT_RNC_RTM
blocksize=4
maxsize=5
maxdiskspace = 200

[Overridables]
maxdiskspace

ADNOPJBMNIGLBKGB
```

4.3.4.2 CCMA Export Initialization File

With an Ini File, it is possible to override default or predefined values of certain parameters.

This file can be modified by the customer in a runtime environment that is opposite to the checksum protected Conf File.

After successfully reading a Conf File, Traffica checks the active workspace directory for a matching Ini File. If such a file is found, Traffica parses it. If the entries listed in the Ini File are overridable, Traffica replaces or modifies the values read from the Conf File accordingly. If there is a syntax error or a parameter is not overridable, Traffica parses the Conf File again and triggers an internal alarm about the invalid file.

- Naming

Ini File name syntax is the same as for Conf File except for the file extension that is different. Ini File name syntax is TrafCCMAE_<DataFilePrefix>.extini.

- Structure

Structure of Ini File is the same as Conf File. However, only parameters that are marked as overridable in the Conf File can be defined in the Ini File.

- Example

```
[Configuration]
  ;<overridable_parameter> = <parameter_value>
  maxdiskspace=250
```

4.3.4.3 CCMA Export Control File

There is one Control File for each Data file. Control File indicates that writing of the Data File with the same name and different extension has been completed. It also contains metadata information about exported counter and vector names, data types, field separator and null value in the Data File.

Naming

Control File name syntax is

TrafCCMAE_<DataFilePrefix>_<SourceName>_<WriteTimestamp>_<WriteTimestamp>_<Index>.ctr

Where:

- <DataFilePrefix> indicates which Conf File is related to this Control File
- <SourceName> is the computer name (hostname) of TNES where this Control File has been generated.
- <WriteTimestamp> is the time stamp of when Control File was created. WriteTimeStamp is in the file name twice to maintain the same file name format than in the RTT Export control files. Report_Time column contains the time stamp of the time class reset time.
- <Index> is a sequence number from 0 to 9. Normally it is 0. If for some reason file with same name already exists, <Index> is incremented by one.

Structure

In this file, Report_Time is a fixed column and contains the time stamp of the time class reset time. The rest of the fields are vector and counter export labels defined in the CCMA, and their data type. Vector and counter data types are always UINT32. Move and sum nodes data types are Double.

The order of the columns is their order of appearance in the CCMA tree.

Example

```
LOAD DATA
INFILE
'trafCCMAE_TRAF_RNC_RTM_CND0390V70_20120606142300_20120606142300_0.dat'
INTO TABLE "TRAFFICA"."TRAF_RNC_RTM"
FIELDS TERMINATED BY ','
OPTIONALLY ENCLOSED BY '"'
(
```

```
        "Report_Time" TIMESTAMP NULLIF BLANKS,
        "MNCID" UINT32 NULLIF BLANKS,
        "RNCID" UINT32 NULLIF BLANKS,
        "BTSID" UINT32 NULLIF BLANKS,
        "CID" UINT32 NULLIF BLANKS,
        "RAB_PS_CALL" UINT32 NULLIF BLANKS,
        "RAB_PS_NORMAL_REL" UINT32 NULLIF BLANKS,
        "RAB_PS_ALL_REL" UINT32 NULLIF BLANKS
)
```

4.3.4.4 CCMA Export Data File

Data File is generated according to Conf File and it contains the actual CCMA counter and vector id data in csv format. Basically, this file carries the data itself.

- <u>Naming</u>

Data File name Syntax is:

TrafCCMAE_<DataFilePrefix>_<SourceName>_<WriteTimestamp>_<WriteTimestamp>_<Index>.ctr

Where:

- <DataFilePrefix> indicates which Conf File is related to this Data File
- <SourceName> is the computer name (hostname) of TNES where this Data File has been generated.
- <WriteTimestamp> is the time stamp of when Data File was created. WriteTimeStamp is in the file name twice to maintain the same file name format than in the RTT Export control files. Report_Time column contains the time stamp of the time class reset time.
- <Index> is a sequence number from 0 to 9. Normally it is 0. If for some reason file with same name already exists, <Index> is incremented by one

- <u>Structure</u>

The number of rows in the Data File is defined by the amount of vectors and the vector sizes. Each vector combination has its own row with relevant vector and counter columns filled with values. The rest of the columns are left empty for that row. The counters on the same vector level are grouped in the same row.

Example

```
2012-06-06 14:23:00,50,180,3858,55696,4,2,2
2012-06-06 14:23:00,50,180,3858,55697,3,1,1
2012-06-06 14:23:00,50,180,3858,55695,2,1,1
2012-06-06 14:23:00,50,180,3858,33525,1,1,1
2012-06-06 14:23:00,50,180,4782,31707,2,2,2
2012-06-06 14:23:00,50,180,4782,31717,1,1,1
2012-06-06 14:23:00,50,180,4782,31705,2,2,2
2012-06-06 14:23:00,50,180,3858,,,4,
2012-06-06 14:23:00,50,180,4782,,,5,
2012-06-06 14:23:00,50,180,,,,9,
```

4.3.5 Real Time Broker (RTB)

RTB is a component used for Customer Experience Management data brokering purposes. It provides a platform for near real-time data collection from network elements and network probes, and offers secure data transfer functionality. RTB can also be used for filtering and pre-processing of the incoming data stream and for reducing the volume of outgoing data using filtering.

The usage of this component leads to reduced data transfer and data storage costs, as well as eases up the load on downstream systems which process the data streams.

Besides that, this component handles RTT Export data or any other CSV format data, runs SQL scripts to process the data and stores the resulting KPIs into KPI database.

4.4 *Traffica and NPM Integration (Suggested Approach)*

Both Traffica and NPM are very complete tools and can provide a lot of different information. However, this particular study needs few competencies and the most important characteristics are presented in the next figure:

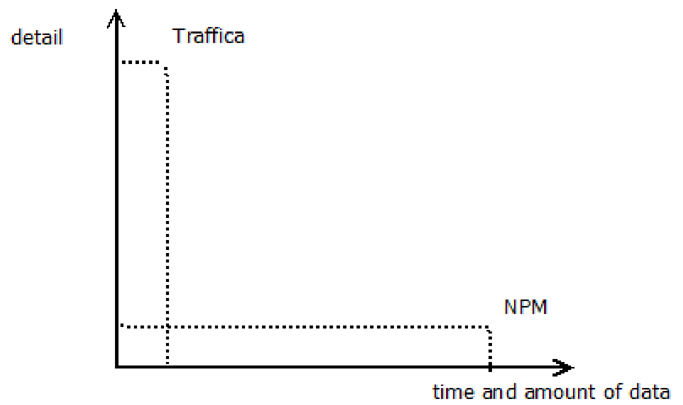


Figure 39: Traffica vs NPM (drawn by the author)

These tools have different purposes and very different features and it would be extremely interesting to have access to huge amount of data and detail of the most important data in one view.

This is possible with the integration of NPM and Traffica. So, with all that was previously presented in mind, a "sketch" about Traffica and NPM interworking is presented next:

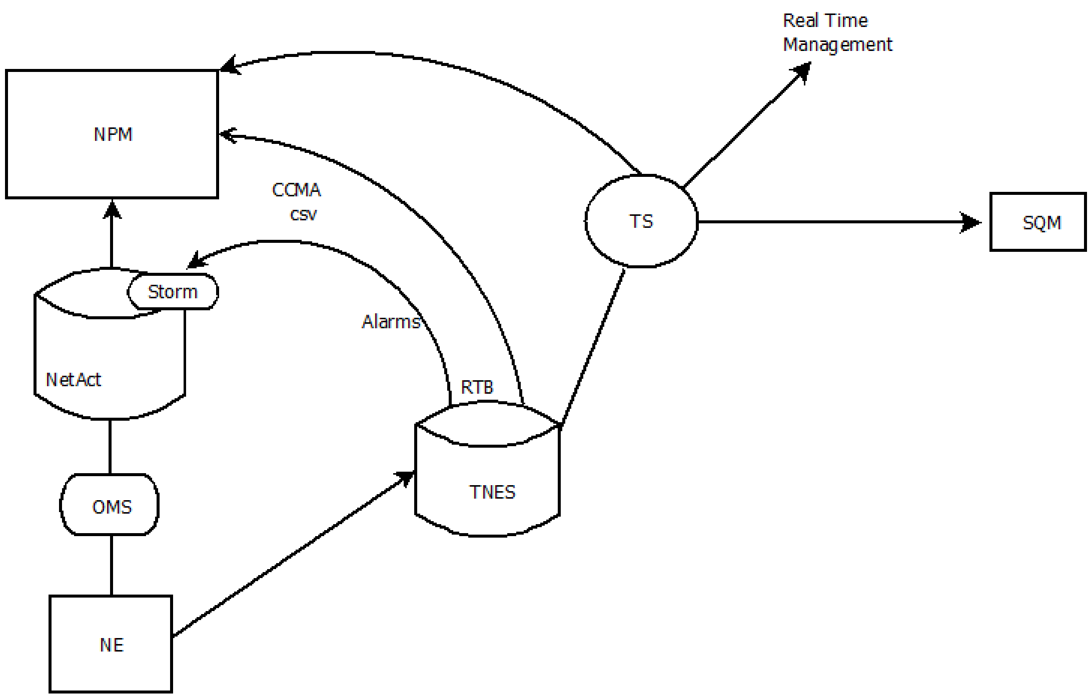


Figure 40 : NPM and Traffica Interworking (Created by the author)

With this figure, it is possible to understand the basic operation and the possible interworking of these two “worlds”. The NEs are connected to both of these worlds and are exchanging the required information. Real time information is exchanged with TNES and “more long term” information with NetAct/NPM. Then, the real time data need to be “passed” in some way to NetAct or NPM. With the acquired information until this point, it seems that CCMA export and RTB have to be included in this integration, but their functionalities and operation need to be deeper analyzed.

4.4.1 RTB vs CCMA

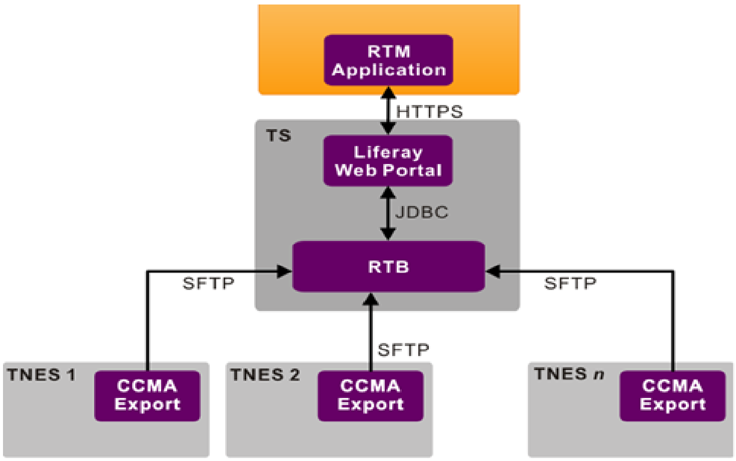


Figure 41: CCMA Export and RTB [12]

As it is possible to observe in the previous figure, the CCMA is best suited for use in TNES level, since it is the basis for graphics and alarms in real time. When a RTT report reaches the TNES, the respective CCMA counters are updated. Usually, the CCMA counters are pre-defined but it is possible to change them and use anyone of the list. The CCMA information is kept in RAM memory and that is why it shouldn’t be too detailed.

RTB provides a platform for near real-time data collection from network elements and network probes, and offers secure data transfer functionality

This is illustrated in the next figure:

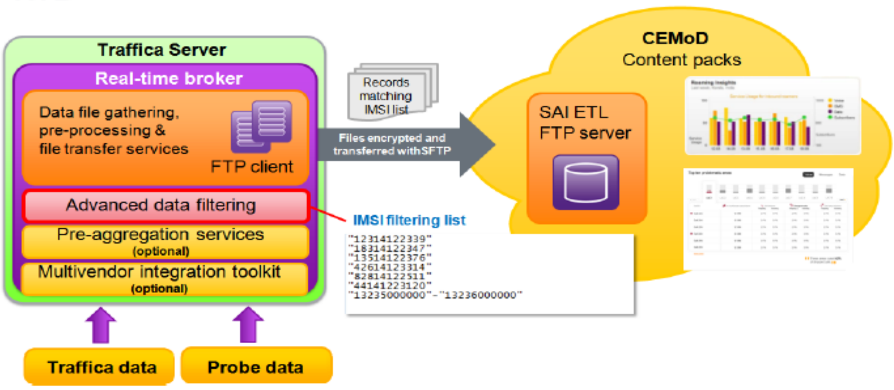


Figure 42: Advanced filtering [12]

RTB can also be used for filtering and pre-processing of the incoming data stream and for reducing the volume of outgoing data using filtering. These features lead to costs reduction.

Besides this, advanced data filtering for e.g. IMSI based filtering could be done via RTB, which can be an interesting feature to this particular work.

RTB is best suited for use in TS level.

With this information, it is possible to conclude that CCMA Export process is mandatory to implement this integration, but RTB is just an optional feature. Because RTB is not a mandatory item, it will stay in “second plan”.

4.4.1.1 Overview of Traffica KPI Export Interface

The understanding of Traffica KPI export Interface may help in the understanding of CCMA Export. This Interface is no longer sold and is superseded by CCMA Export. However, it constitutes the “ancestor” of the existing interface and there are still several existing customers that have KPI interface.

Main Focus:

- Provide Traffica’s PM interface towards NetAct
- Make Traffica CCMA data available for other NetAct applications
- Offer set of pre-defined and pre-calculated KPIs based on post processed counter data

Key benefits:

- Utilize Traffica data for service assurance and service reporting
- Provide data in short time intervals
- Transfer only relevant data from Traffica to NetAct by setting filter criteria
- Offer a set of pre-defined KPIs and counters for customer use
- Configuration only on Traffica – no configuration needed on NetAct

In this configuration, the RTT server on TNES receives RTT reports from the NE and updates Traffica CCMA based on the content of the RTT Reports. The TS receives new KPIs from TNES and creates result files in XML format. Then, the resulting files are transferred to NetAct PM Pipe using FTP and the NetAct PM Pipe inserts the data into the NetAct Database.

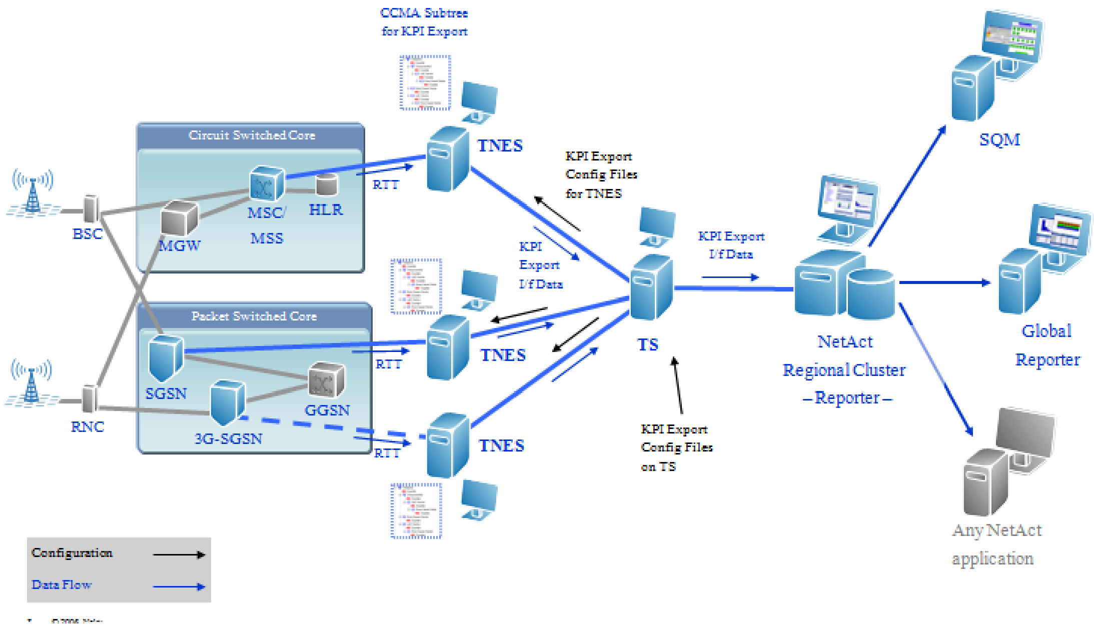


Figure 43: Architecture, Configuration and Data Flow [50]

Files in TS and TNES:

<u>Traffica Server:</u>

- Predefined Measurement Configuration Files for making subscriptions to TNES
- Data Destination File that contains the receiver of measurement data
- Parameter File that defines active and inactive measurements

<u>Traffica Network Element Server:</u>

- KPI Export CCMA Definition Files contain configuration for KPI Export CCMA
- KPI Export Open Node Definition Files are used to customize what objects are measured and how they are grouped

The main difference is that in this case, TS is the element that handles the export procedure and the data is exported to NetAct, while in CCMA Export, this operation is handled by TNES and the data is exported directly to NPM.

4.4.2 Traffica CQI Monitor for Voice and Messages

The understanding of this application is important because it already exists and its approach meets the main goals of this dissertation.

Traffica CQI Monitor for Voice and Messages monitors the CS Core Network performance through KPIs. These KPIs measure calls, SMSs, handovers and quality of service for voice calls. It is designed to identify core and radio related problems across the CS Core Network in real time.

Architecture Overview:

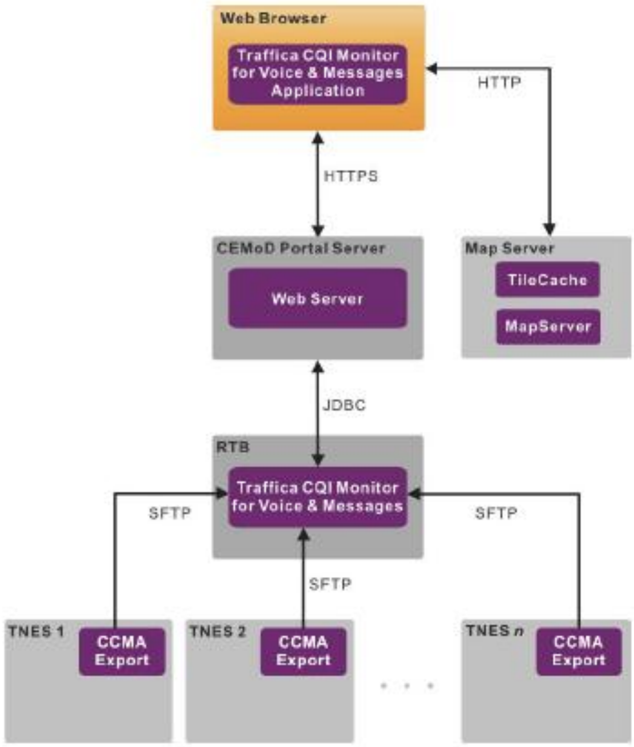


Figure 44: Overview of Traffica CQI Monitor for Voice and Messages architecture [18]

The main difference between this and the wanted integration is that in this case, the counters and KPIs are used and presented “inside” Traffica. We want to use similar KPIs but present them in NPM in order to have the integration with long term data.

In this application, the TNES elements at the lowest layer provide network element interfaces and raw data processing like counter calculation, for an example. One layer above TNESs is the RTB, which is a centralized entity that provides the KPI calculation and aggregation. RTB also implements a database, which is accessed by portal application users. The Map Server can be an offline server located on the customer premises, or a public server accessed remotely over the Internet. The end user uses the web browser to monitor network performance KPIs as reported by the CEMoD Portal Server.

This application is designed to identify problems at MSS, MGW, RNC, BSC, LAC, 3G SAC and 2G cell levels and it “uses” the following KPIs: call failure ratio, call setup failure ratio, dropped call ratio, average call duration, SMS failure ratio, Handover failures and bad voice quality ratio. As it is possible to observe, some of those KPIs may be important to our work, and this approach may be used as a guide for the KPIs to be presented in this work.

Set of KPIs for this application:

Call Attempts	
Description	Number of call attempts

Answered Calls	
Description	Number of answered calls

Dropped Calls	
Description	Number of dropped calls

Call Setup Failures	
Description	Number of non-answered calls failing in any of following call stages: setup, assignment and ringing

Failed Calls	
Description	The number of all failed calls
Formula	Call Setup failures + Dropped Calls

Handover Failures	
Description	Counts the number of failed handovers which have clear codes belonging to one of the failure groups
Notes	All types of handovers are counted for this KPI

Dropped Call Ratio	
Description	This KPI counts failure ratio for answered calls which have clear codes belonging to one of the failure groups
Formula	Dropped calls/Answered calls * 100

Call Failure Ratio	
Description	Counts failure ratio for all calls(non-answered and answered calls) which have clear codes belonging to one of the failure groups
Formula	Failed Calls / Call Attempts *100

Call Setup Failure Ratio	
Description	This KPI counts failure ratio for non-answered calls which have clear code belonging to one of the failure groups
Formula	Call Setup failures / Call Attempts * 100
Notes	Failing non-answered calls can reach any of the following call stages: setup, assignment and ringing.

This set of KPIs is helpful because it enforces the idea of what are the most important counters and KPIs in voice calls context.

Knowing this set of KPIs and considering what was previously studied, a proposal of KPIs for this implementation will be presented over the next chapters.

5. Counters and KPIs (MSS related)

After the study that was previously presented, this represents a more practical work.

It is already known that is possible to transfer data from Traffica to NPM using CCMA Export, so it is time to understand what data is worth to transfer. At this point, it is important to understand which counters from Traffica can be used to "form" some basic, but at the same time useful KPIs to be integrated in NPM. In this chapter, the focus will be the MSS and all the counters and KPIs that will be presented are MSS related.

The MSC/MSS is a fundamental part of the network and can be considered the "brain" behind the voice calls setup. After analyzing the "Call Set-Up Procedures" sub section we have an idea of its importance, since it is the central NE that is responsible for the establishment of the calls.

So, it is important to monitor real time data that is related to the establishment of a call. In this first approach, a set of KPIs that can "translate" the good network operation regarding voice calls will be presented.

Before the KPIs presentation, note that:

➔ Note that it would be interesting to have traffic related data, but with Traffica, it is not possible to retrieve the amount of traffic based on Erlangs. Erlang is a unit that is used as a measure of carried load on service providing elements. As Traffica provides minute-based information, the traffic is not that important and that is why there aren't counters regarding this issue.

➔ All of these previously presented KPIs are to run at MSC level, or in other words, the data that is presented is grouped by MSC.

➔ Next, the KPIs are to run at clear code level which means that in this case, the data is grouped and presented by clear codes.

➔ Clear codes have hexadecimal format and represent how the call has ended (successful or unsuccessful).

➔ The Clear Codes are presented in Appendix A, and the most relevant RTT Report fields (at least for this work) are presented in Appendix D.

KPIs

Based on "***Traffica - Traffica Reference Guide for 2G3G - dn98904766***" document ([13]).

This document lists all the Traffica counters that are related to MSS.

- **Time Classes:**

In the Time Class **TRAF 3G_Daily**, the data is collected during the current day, starting from midnight when the counters are initialized, up to the present moment.

The Time Class **TRAF 3G_30 min+24h** consist of two time resolutions:

➔ **TRAF 30 min** collects data for the latest 30 minutes in one-minute slices.
➔ **TRAF 24h** collects data for the 24 hours preceding the 30 minute period in one hour slices.

The Time Class **TRAF 3G_24h** collects data for the last 24 hours, in one hour slices.

If either the A or B subscriber is a 3G mobile subscriber, the call is counted as a 3G call in 3G CCMA.

- **KPIs**

5.1 MSC Level

KPIs to run @MSC level	
KPI name	**CSSR = Call Setup Success Ratio**
Description	This KPI provides the 3G call setup success ratio.
Unit	%
KPI formula	$\frac{\sum \text{All\_CC} - \left(\sum \text{Int\_cong\_CC} + \sum \text{Ext\_Cong\_C C} + \sum \text{Subs\_Error\_CC}\right)}{\sum \text{All\_CCs}} \times 100$
Traffica used counters	➔ **All_CC** Counts the number of calls and call attempts which have ended in any clear code. RTT Report\Clear Code Exists\Counter

	Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 **➔ Int_Cong_CC** **Internal Congestion Clear Codes** Counts the number of calls or call attempts which ended with a clear code between **400-7FF** in hex. RTT Report\Clear Code Exists\Clear Codes 400-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 **➔ Ext_Cong_CC** **External Congestion Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **800-BFF**. RTT Report\Clear Code Exists\Clear Codes 800-BFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 **➔ Subs_Error_CC** **Subscriber Errors Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **C00-FFF**. RTT Report\Clear Code Exists\Clear Codes C00-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	This KPI provides: $\frac{\sum \text{3G\_Normal\_Clearing}}{\sum \text{3G\_ All\_Clear\_Codes}}$ Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files.

0800H - 0BFFH → External congestion
Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections.

0C00H - 0FFFH → Subscriber errors
Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling.

Or another approach:

KPI name	**CSSR = Call Setup Success Ratio**
Description	This KPI provides ratio of successful 3G calls setup
Unit	%
KPI formula	$$\frac{\sum(3G\_Setup\_Count - 3G\_Setup\_Failure\_Count)}{\sum 3G\_Setup\_Count}\times 100$$
Traffica used counters	**→ 3G_Setup_Count** Counts the number of all calls and call attempts. RTT Report\All Reports Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 **→ 3G_Setup_Failure_Count** Counts the number of all calls and call attempts with empty “Signaling Complete Time” field in RTT Report. RTT Report\All Reports Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	Call Setup is considered failed when Traffica’s RTT Report field ‘Signaling Complete Time’ is empty.

KPI name	**CAR = Call Answered Ratio**
Description	This KPI provides ratio of 3G calls that had been answered.
Unit	%
KPI formula	$$\frac{\sum 3G\_Answ\_Calls}{\sum 3G\_All\_Calls}\times 100$$

Traffica used counters	➔ **3G_Answ_Calls** Counts the number of answered calls. RTT Report\Call Answered\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h, TRAF 3G_24h Version M13, M14, M15, M16, M16.1 ➔ **3G_All_Calls** Counts the number of all calls and call attempts. RTT Report\All Reports Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	The call is considered answered when the field ‘ B_Answered_Time’ in RTT Report is not empty

KPI name	**CCSR = Call Completion Success Ratio**
Description	This KPI provides ratio of 3G calls that have ended with the CC 0 = “Normal end of the call”.
Unit	%
KPI formula	$\frac{\sum \text{3G\_Ended\_Calls}}{\sum \text{3G\_All\_Calls}} \times 100$
Traffica used counters	➔ **3G_Ended_Calls** Counts the number of ended calls. RTT Report\Call Answered\Call Ended\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 ➔ **3G_All_Calls** Counts the number of all calls and call attempts. RTT Report\All Reports Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**3G Conversation time**
Description	This KPI provides the 3G total conversation time.

Unit	Min
KPI formula	$$\frac{\sum 3G\_Conv\_Time}{60}$$
Traffica used counters	➔ **3G_Conv _Time** Sums the durations of all calls which were answered and ended. RTT Report\Call Answered\Call Ended\Call Length\Sum Time Class TRAF 3G_Daily, TRAF 3G_24h Version M13, M14, M15, M16, M16.1
Special Notes	The division by “60” was added because it was assumed that the 3G_Conv_Time is provided in seconds. The call duration is calculated in the following way: ‘Charging_End_Time’ – ‘B_Answered_Time’ , that are RTT Reports fields

KPI name	**Average call duration**
Description	This KPI provides the 3G average call duration.
Unit	Min
KPI formula	$$\frac{\left(\sum 3G\_Conv\_Time\right)/60}{\sum 3G\_Answ\_Calls}$$
Traffica used counters	➔ **3G_Conv _Time** Sums the durations of all calls which were answered and ended. RTT Report\Call Answered\Call Ended\Call Length\Sum Time Class TRAF 3G_Daily, TRAF 3G_24h Version M13, M14, M15, M16, M16.1 ➔ **3G_Answ_Calls** Counts the number of answered calls. RTT Report\Call Answered\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h, TRAF 3G_24h Version M13, M14, M15, M16, M16.1
Special Notes	The division by “60” was added because it was assumed that the 3G_Conv_Time is provided in seconds.

KPI name	**3G conversation time per dropped call**
Description	This KPI provides the 3G conversation time per dropped call.
Unit	Min

KPI formula	$$\frac{\left(\sum 3G\_Conv\_Time\right)/60}{\sum 3G\_Drop\_Call}$$
Traffica used counters	➔ **3G_Conv _Time** Sums the durations of all calls which were answered and ended. RTT Report\Call Answered\Call Ended\Call Length\Sum Time Class TRAF 3G_Daily, TRAF 3G_24h Version M13, M14, M15, M16, M16.1 ➔ **3G_Drop_Call** Counts the number of dropped calls. RTT Report\Call Answered\Call Dropped\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	The division by "60" was added because it was assumed that the 3G_Conv_Time is provided in seconds.

KPI name	**Abnormal calls**
Description	This KPI provides the number of abnormal calls calculated in a real time basis.
Unit	#
KPI formula	$$\sum \mathrm{Int\_cong\_CC} + \sum \mathrm{Ext\_Cong\_CC} + \sum \mathrm{Subs\_Error\_CC}$$
Traffica used counters	➔ **Int_Cong_CC** **Internal Congestion Clear Codes** Counts the number of calls or call attempts which ended with a clear code between **400-FFF** in hex. RTT Report\Clear Code Exists\Clear Codes 400-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 ➔ **Ext_Cong_CC** **External Congestion Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **800-BFF**. RTT Report\Clear Code Exists\Clear Codes 800-BFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1

	➔ **Subs_Error_CC** **Subscriber Errors Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **C00-FFF**. RTT Report\Clear Code Exists\Clear Codes C00-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling.

KPI name	**3G Call Drop Ratio**
Description	This KPI provides the Call drop ratio calculated in a real time basis.
Unit	%
KPI formula	$\frac{\sum 3G\_Drop\_Calls}{\sum 3G\_Answ\_Calls} \times 100$
Traffica used counters	➔ **3G_Drop_Calls** Counts the number of dropped calls. RTT Report\Call Answered\Call Dropped\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 ➔ **3G_Answ_Calls** Counts the number of answered calls.

	RTT Report\Call Answered\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h, TRAF 3G_24h Version M13, M14, M15, M16, M16.1
Special Notes	Call is considered dropped if it is answered and has ended with Clear code other than zero

KPI name	**3G Total Calls**
Description	This KPI provides the total number of 3G calls in a real time basis.
Unit	#
KPI formula	$\sum 3G\_All\_Call$
Traffica used counters	➔ **3G_All_Calls** Counts the number of all calls and call attempts. RTT Report\All Reports Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**Success Calls**
Description	This KPI provides the number of success calls calculated in a real time basis. Note that Successful Calls are the calls that ended with a clear code within the range 0000H – 03FFH (Normal Clearing CCs).
Unit	#
KPI formula	$\sum \mathrm{All\_CC} - \left(\sum \mathrm{Int\_cong\_CC} + \sum \mathrm{Ext\_Cong\_CC} + \sum \mathrm{Subs\_Error\_CC}\right)$
Traffica used counters	➔ **All_CC** Counts the number of calls and call attempts which have ended in any clear code. RTT Report\Clear Code Exists\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 ➔ **Int_Cong_CC** **Internal Congestion Clear Codes** Counts the number of calls or call attempts which ended with a clear code between **400-FFF** in hex.

	RTT Report\Clear Code Exists\Clear Codes 400-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 ➔ **Ext_Cong_CC** **External Congestion Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **800-BFF**. RTT Report\Clear Code Exists\Clear Codes 800-BFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 ➔ **Subs_Error_CC** **Subscriber Errors Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **C00-FFF**. RTT Report\Clear Code Exists\Clear Codes C00-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1
Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling.

5.2 *Clear Code level:*

It is important to have KPI(s) at clear code level because they allow more detail and add valuable information to the operator. The clear codes translate the termination reasons and may either indicate success or the failure reasons.

KPIs to run @Clear Code level: (MSC) → (Clear Code)

KPI name	**Abnormal calls per failed reason**
Description	This KPI provides the percentage of certain clear code ranges.
Unit	%
KPI formula	$\frac{\sum Int\_Cong\_CC < or > \sum Ext\_Cong\_CC < or > \sum Subs\_Error\_CC}{\sum \mathrm{Int\_cong\_CC} + \sum \mathrm{Ext\_Cong\_CC} + \sum \mathrm{Subs\_Error\_CC}} \times 100$
Traffica used counters	→ **Int_Cong_CC** **Internal Congestion Clear Codes** Counts the number of calls or call attempts which ended with a clear code between **400-FFF** in hex. RTT Report\Clear Code Exists\Clear Codes 400-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 → **Ext_Cong_CC** **External Congestion Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **800-BFF**. RTT Report\Clear Code Exists\Clear Codes 800-BFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1 → **Subs_Error_CC** **Subscriber Errors Clear Codes** Counts the number of calls and call attempts that ended in a clear code within the range **C00-FFF**. RTT Report\Clear Code Exists\Clear Codes C00-FFF\Counter Time Class TRAF 3G_Daily, TRAF 3G_30min+24h Version M13, M14, M15, M16, M16.1

Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling. Abnormal calls = (Internal congestion) + (External congestion) + (Subscriber errors)

It is also important to present those same clear code occurrences per call phase. This information would allow deeper analysis and would facilitate the understanding of call problems. In this case, the phases to be considered are: signaling, ringing and speech.

- <u>Signaling Phase</u> ⇨ call phase between CM_Service_Request and Assignment Complete. In terms of Traffica, Signaling phase is indicated by Traffica RTT report field “Signaling Complete Time”. If this field is empty, it means that the call ended in signaling phase.

- <u>Ringing Phase</u> ⇨ call phase between Alerting and Connect signaling messages. In terms of Traffica, Ringing phase is indicated by Traffica RTT report where “Signaling Complete Time” field is not empty, but “B_Answered_Time” field is empty.

- <u>Speech Phase</u> ⇨ call phase between Connect and Release Complete signaling messages. In terms of Traffica, Speech phase is indicated by Traffica RTT Report where “B_Answered_Time” field is not empty

The next figure illustrates these call phases:

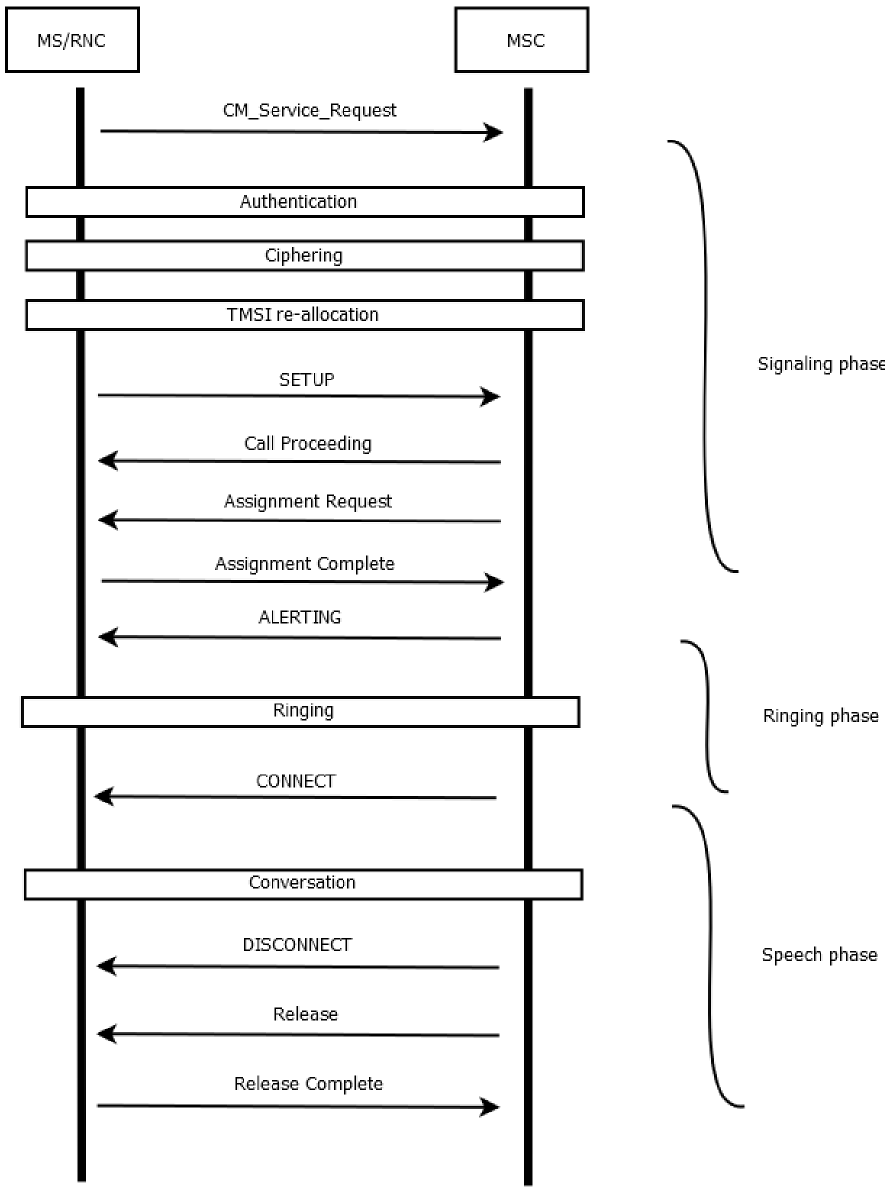


Figure 45: Considered call phases illustration (drawn by the author)

5.3 LAC Level

Note that LAC means Location Area Code and SAC means Service Area (SA) code.

The SA identifies an area of one or more cells of the same LA (Location Area) and is used to indicate the location of a UE (User Equipment) to the CN (Core Network).The combination of SAC (Service Area Code), PLMN-Id (Public Land Mobile Network Identifier) and LAC (Location Area Code) is the Service Area Identifier (SAI).

SAI = PLMN-Id + LAC + SAC

KPIs to run @LAC level: (MSC) → (LAC)

KPI name	**Pagings per SAC**
Description	This KPI provides the total number of paging per SAC.
Unit	#
KPI formula	$Paging\_SAC$
Traffica used counters	➔ **Paging_SAC** Counts the number of paging VLR events for each SAC. VLR Report\Paging\SAC Vector\Counter Time Class TRAF 3G MSC VLR Extra Info, Daily Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**Location Updates**
Description	This KPI provides the number of Location Updates per VLR MSC.
Unit	#
KPI formula	$\sum HomeSubs\_LU + \sum RoamSubs\_LU$
Traffica used counters	➔ **HomeSubs_LU** Counts the number of location update VLR reports for home subscribers VLR Report\Home LU\Counter Time Class TRAF MSC Report Types Version M13, M14, M15, M16, M16.1 ➔ **RoamSubs_LU** Counts the number of location update VLR reports for roaming subscribers VLR Report\Roaming LU\Counter

	Time Class TRAF MSC Report Types Version M13, M14, M15, M16, M16.1
Special Notes	Provide data for the VLR-MSC level.

KPI name	**Abnormal Calls per LAC**
Description	This KPI provides the number of abnormal clear codes per LAC
Unit	#
KPI formula	FOR <LAC> WHERE <CC> IN RANGE [(0400H - 07FFH) + (0800H - 0BFFH) + (0C00H - 0FFFH)] $\sum CC\_LAC$
Traffica used counters	➔ **CC_LAC** Counts the number of calls and call attempts that have ended in a certain clear code in a certain LAC (A subscriber) RTT Report\LAC Vector\Clear Code Vector\A Release\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling. Abnormal calls = (Internal congestion) + (External congestion) + (Subscriber errors)

5.4 Final remarks about this chapter

First of all, MSS can be considered the main focus of this work because it is a key element in telecommunications networks. During a voice call establishment, for an example, this element exchanges a lot of messages with MGW, HLR, RNC, and with other MSSs and is fundamental in this process. Note that its main functions were already referred in a previous chapter, as well as the call set up procedures.

The next figure eases the understanding of the importance of the specific presented KPIs. Because CS main service is the voice calls, this figure represents a call and where the various KPIs “fit” within the call.

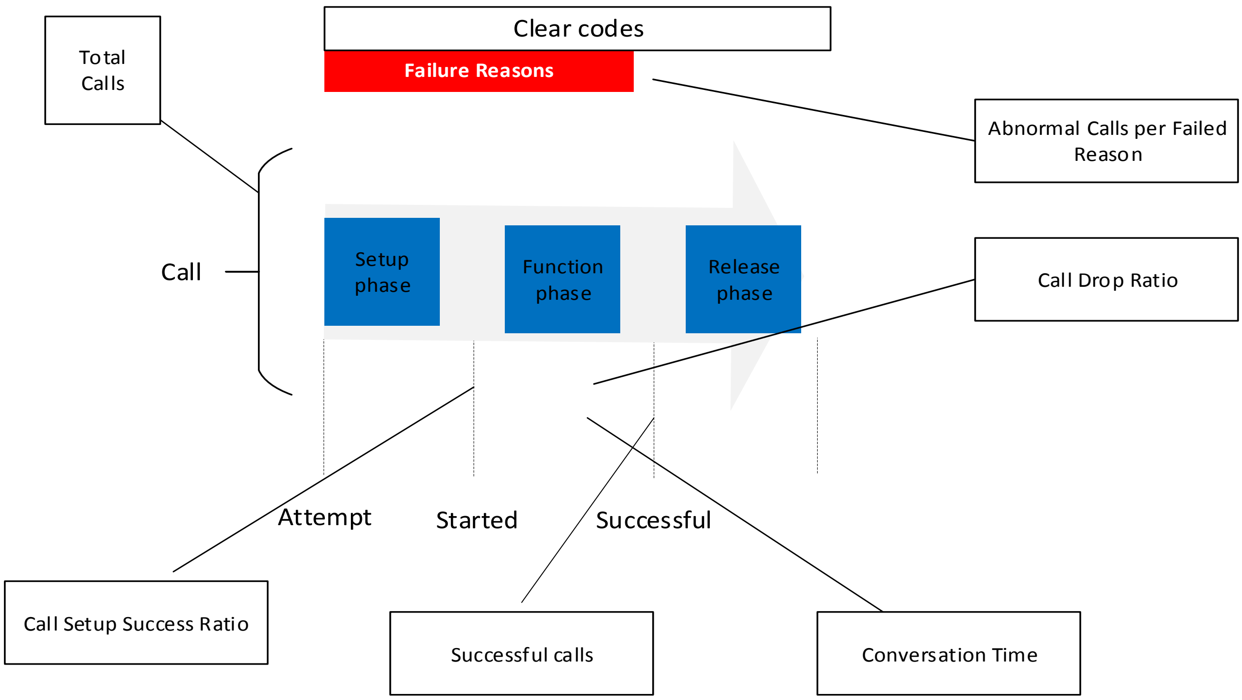


Figure 46: Chosen KPIs illustration (drawn by the author)

This set of KPIs allows coverage to the various steps of a voice call and provide information about the most important issues.

Note that in this first approach, the KPIs that are supposed to run at LAC level won´t be considered.

Another point that is important to clarify is the importance of clear codes. As it is possible to observe in previous sub-chapters, clear codes represent how the call has ended (successful or unsuccessful) and they are identified with hexadecimals between 0000H and FFFFH. In the appendix A, there is a list of the clear codes to be considered and a small description.

When a call ends, a clear code is generated in order to specify the reason why that same call has ended. This is very helpful information and clear codes should be considered a fundamental concept in networks management

As they provide very important information about the calls, they should be a common point in Traffica and in NPM and may work as a "bridge" for this integration. Since the proposed KPIs are similar in both cases, clear codes may be a good way to get to a common understanding, as it is represented in the following figure:

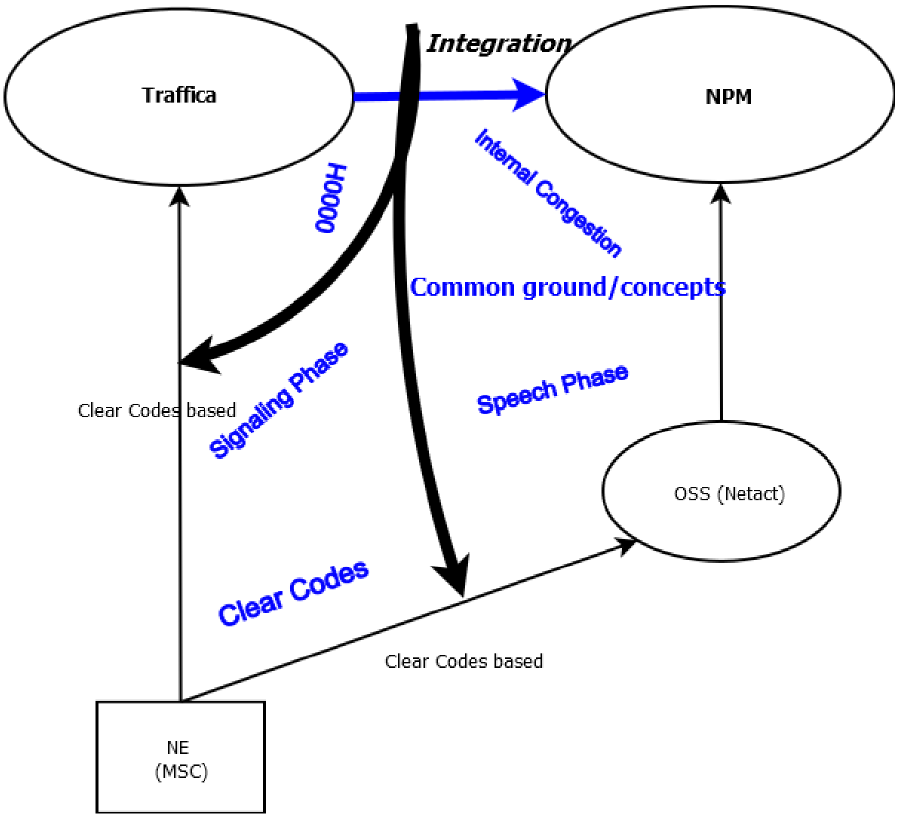


Figure 47: Traffica and NPM integration common ground (drawn by the author)

6. Other Possible Features

Until this stage, this work was more focused in MSS. Although it may be considered the most relevant element of this integration, there are other possible features that may add some value and that is why they will be presented.

After analyzing the MSS related KPIs and counters, it may be interesting to present a set of "parallel" KPIs related to MGW and SGSN.

Have in mind that the MSS related KPIs that were chosen to give a network overview and were considered the most important are the following:

- Call Setup Success Ratio
- Total Conversation Time
- Average Call duration
- Conversation time per Drop
- Call Dropped Ratio
- Total Calls
- Successful Calls
- Failure Calls

So, with that in mind, we'll try to follow the same approach to MGW and SGSN.

6.1 MGW

In this sub-section, I will study the MGW counters from Traffica and will present a set of KPIs that can be worth analyzing in a real time basis and may be used in a future implementation.

6.1.1 Introduction

As it was previously referred, the MGW is responsible for the user plane. This means that its focus is on user plane transmission and their QoS experience. The Traffica real time monitoring allows the operator to discover the "true" voice quality delivered to subscribers. With the MSS presented KPIs it is possible to know a lot of valuable information, but the voice quality may be a "blind spot". It is possible to know if a call failed and why, but is not possible to know the voice/call quality of a successful call. On the other hand, with MGW related KPIs it is possible to have information about that quality and that is why the integration with NPM may be an interesting issue.

The next figure represents the MSS and MGW different "responsibilities":

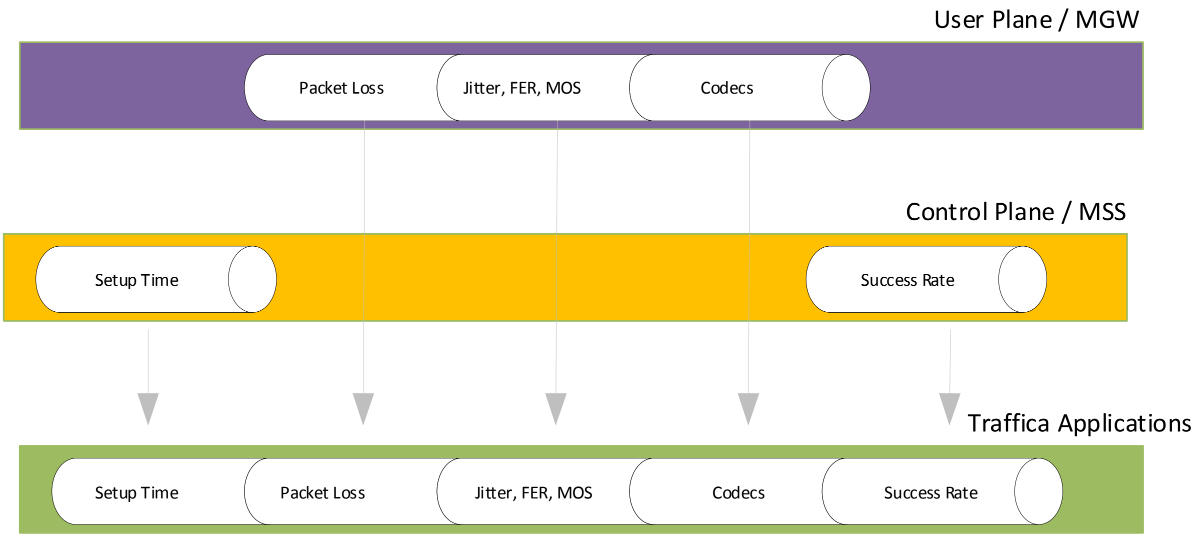


Figure 48: MSS and MGW different "responsibilities" (based on [28])

After a first analysis, there is some information that Traffica can provide that may make sense to integrate with NPM [29]:

(Note that at this point, this is only informative. Further on, not all the presented information will be considered)

- Jitter information in IP physical terminations: Jitter indicates IP network packet transfer delay variation and tells about the quality of IP transport network. It may give indication on problems of IP network before actual packet loss is happening. Packet loss affects the speech quality.

- Out of order IP packets: as jitter, also out of order packets tell about delay variation in IP network. This information indicates how many packets are received in wrong order according to their serial number. This information may indicate IP network overload.

- Inter-Arrival Jitter: This is a short term jitter calculated over the last packets of a call. Inter-Arrival Jitter gives an overview of the network level jitter trend as there is a huge number of terminated calls in every second. According to IEEE, “we measure the difference in packet spacing of voice packets at the receiver compared to that at the sender. The difference, inter-arrival jitter is used as a measure of the quality for real time voice applications.

- Active Speech Level information: This indicates the gain of speech in processed call. If it is too loud or too silent, it may not be interpreted by the recipient.

- Noise Level: This is important because if the noise is too loud, the recipient cannot interpret the speech.

- Speech activity factor: Indicates how much one party is speaking in a call. This may indicate some errors. If speech level is very high it can mean that signaling frame is accidentally conveyed as speech, for an example.

- Double Talk: Indicates how much both parties in the call are talking at the same time. If this value is high, it may indicate long delays, for an example.

- MOS (Mean Opinion Score) simulation: Gives speech quality indication for the connection, based on customer feedback.

- Degraded Seconds: A degraded second is defined in ITU-T as a block of packets observed during a 1 second interval in which the ratio of lost packets to total packets exceeds 15%. For example, if a flow of 50 packets per second is impaired by 8 losses (16%), then the quality will be degraded whether the losses are consecutive or not. So, this is considered a degraded second.

- Link FER (Frame Erasure Ratio): It is a fundamental measure of CDMA voice quality. Increased values would mean connection problems which could translate into low voice quality. Because it may be a voice quality indicator, this value may be relevant to our study.

  This value is calculated as a ratio of all received bad frames from the current link excluding SID frames. Link FER is the closest estimate possible of the FER of the current link. It is calculated as:

  (link_bad_frames*10000) / total_number_of_received_frames

- Packet Loss (%): Packet loss degrades the speech quality as speech codecs need to compensate for lost packets. Packet Loss describes the ratio of lost Packets to the sum of all transmitted packets.

  High values indicate transmission problems between Node B and MGW, and speech may be lost in transmission. When Packet loss is detected from network, every other transmission related parameters should be investigated.

Terminations are abstractions that represent connections, and a context is an association between a number of terminations for the purpose of sharing data between those terminations. Normally, the context is created by an MGW when the MSC Server adds the first termination to it. Each context has an identifier that is unique within one Physical MGW.

In this case, there are two types of terminations to be considered: Physical and Ephemeral.

Physical Terminations represent physical entities that have a semi-permanent existence, like a Termination representing ports on the gateway, such as TDM channel. TDM termination is allocated by MSC Server and ATM and IP terminations are dynamically allocated by MGW.

Ephemeral terminations represent connections or data flows and usually exist only during the duration of their use in a particular context. Ephemeral terminations are, for an example, RTP streams or switched ATM virtual connections that exist only during the call.

The Terminations to be considered in KPI proposal are Physical Terminations.

6.1.2 Counters and KPIs

After this first analysis, we will now analyze the counters presented in "Traffica Reference Guide for MGW Direct Interface-dn70497645" ([29]).

This document lists all the Traffica counters that are related to MGW.

In this case, there are two time classes in the CCMA: 24 hours and 30 minutes.

The time class 24 hours collects data hourly for the last 24 hours. There are separate counters for each hour for the last 24 hour period. Counters are reset and initialized at the beginning of each hour.

The time class 30 minutes collects data minutely for the last 30 minutes. There are separate counters for each minute for the last 30 minute period. Counters are reset and initialized every minute. For an example, at 12:00, there will be minutely counters available until 11:30.

KPIs to run @MGW level

In NPM, there are some KPIs that give context related information.

Knowing the context and termination concepts, it would be interesting to present some real time KPIs with context information. However, MGW RTT Reports are sent per Termination, not per context.

The MGW interfaces and equivalent terminations are represented in the following figure:

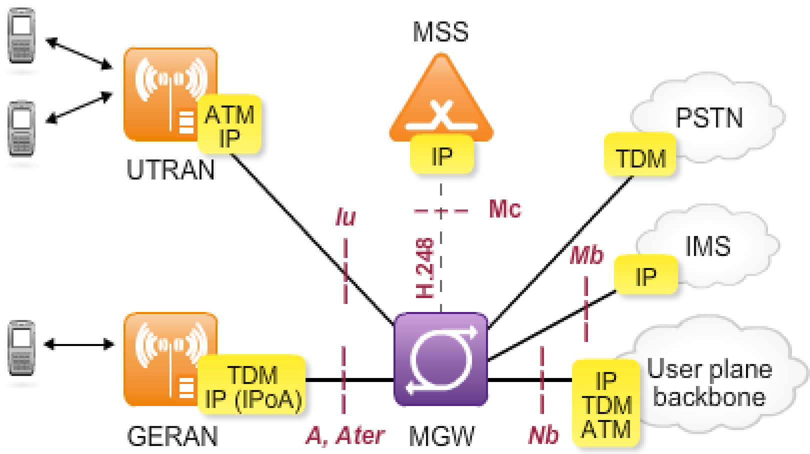


Figure 49: MGW Interfaces [64]

In order to establish a parallel with CSSR, it is possible to define a success terminations ratio KPI in the following way:

In terms of originating voice calls handling, TDM is related to 2G calls and ATM and IP to 3G calls.

KPI name	**Termination Success Ratio**
Description	This KPI provides ratio of successful terminations
Unit	%
KPI formula	$$\frac{\sum(TDM\_Term - Failed\_TDM\_Term) + \sum(ATM\_Term - Failed\_ATM\_Term) + \sum(IP\_Term - Failed\_IP\_Term)}{\sum \mathrm{TDM\_Term} + \sum ATM\_Term + \sum IP\_Term} \times 100$$
Traffica used counters	➔ **Failed_TDM_Term** Counts Failed TDM Terminations per each Physical MGW MGW Termination Report\Physical MGW Vector\TDM Termination\Failed Termination\ Failed TDM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **TDM_Term** Counts TDM Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\TDM Termination\ TDM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **Failed_ATM_Term** Counts Failed ATM Terminations per each Physical MGW MGW Termination Report\Physical MGW Vector\ATM Termination\ Failed Termination\Failed ATM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **ATM_Term** Counts ATM Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\ATM Termination\ ATM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **Failed_IP_Term** Counts Failed IP Terminations per each Physical MGW MGW Termination Report\Physical MGW Vector\IP Termination\ Failed Termination\Failed IP Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **IP_Term**

	Counts IP Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\IP Termination\IP Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes
Special Notes	

Following this thought, the next presented KPIs may also be considered:

KPI name	**Total Terminations Attempts**
Description	This KPI provides the number of Termination Attempts
Unit	#
KPI formula	$\sum(\mathrm{TDM\_Term} + ATM\_Term + IP\_Term)$
Traffica used counters	→ **TDM_Term** Counts TDM Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\TDM Termination\TDM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes → **ATM_Term** Counts ATM Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\ATM Termination\ATM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes → **IP_Term** Counts IP Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\IP Termination\IP Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes
Special Notes	

KPI name	**Successful Terminations**
Description	This KPI provides the number of successful terminations
Unit	#
KPI formula	$\sum(TDM\_Term - Failed\_TDM\_Term)$ $+\sum(ATM\_Term - Failed\_ATM\_Term) + \sum(IP\_Term - Failed\_IP\_Term)$
Traffica used counters	➔ **Failed_TDM_Term** Counts Failed TDM Terminations per each Physical MGW MGW Termination Report\Physical MGW Vector\TDM Termination\Failed Termination\ Failed TDM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **TDM_Term** Counts TDM Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\TDM Termination\ TDM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **Failed_ATM_Term** Counts Failed ATM Terminations per each Physical MGW MGW Termination Report\Physical MGW Vector\ATM Termination\ Failed Termination\Failed ATM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **ATM_Term** Counts ATM Termination Attempts per each Physical MGW MGW Termination Report\Physical MGW Vector\ATM Termination\ ATM Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **Failed_IP_Term** Counts Failed IP Terminations per each Physical MGW MGW Termination Report\Physical MGW Vector\IP Termination\ Failed Termination\Failed IP Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes ➔ **IP_Term** Counts IP Termination Attempts per each Physical MGW

	MGW Termination Report\Physical MGW Vector\IP Termination\IP Counter Time Class TRAF MGW Traffic, 24 Hours, 30 Minutes
Special Notes	

To establish a parallel with 'Failure Calls', a MEGACO (H.248) related KPI may be presented. It is important to monitor this protocol because it represents an interface between signaling units of MSS and MGW for control purpose. As it is possible to observe in the next figure, the Mc link is used for the MSS and MGW interconnection and that link is based on H.248 protocol. This protocol may sit over the SCTP or TCP protocols which, in its turn, will work over the IP and Ethernet protocols.

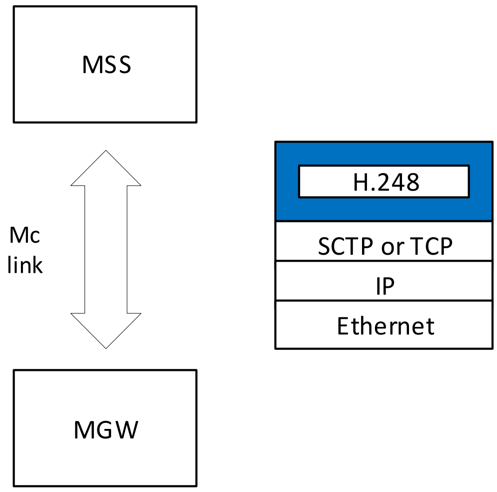


Figure 50: Mc link (based on [10])

By using the H.248 protocol, MSC Server may request MGW to create, remove and modify a transmission connection [41], and this connection is formed by using contexts and terminations. Besides that, it is also possible to instruct the MGW to provide tones, perform echo cancelling, handle call interception and perform speech coding, for example.

KPI name	**MGW Termination per error code**
Description	This KPI represents the number of MGW terminations per error code
Unit	#
KPI formula	ERR_H248
Traffica used counters	➔ **ERR_H248** Counts Termination Attempts per each Physical MGW for each H.248 error code

	MGW Termination\H248 Error Vector\Physical MGW Vector\Counter Time Class TRAF MGW Traffic, 24 hours, 30 minutes
Special Notes	- Error codes can be considered as the clear codes parallel for MGW

Besides these KPIs, it is also important to present some KPIs that allow the operators to have information about the voice quality of the calls. It is important to be able to monitor the voice quality due to the following reasons:

- The speech quality impacts the revenue. Subscribers experiencing low voice quality will shorten their calls and may switch to another operator
- Measuring the speech quality creates a better service, because customer care team can better respond to subscriber complaints if it has access to voice quality measurements
- Fast detection of bad voice quality reduces the OPEX
- Being able to measure the actual voice traffic leads to accurate planning of MGW interface expansions

Hence, some KPIs that may be important to the understanding of that quality are shown below.

KPI name	**Active Speech Level Ratio**
Description	This KPI provides ratio of Active Speech Level measurements that are over the limit
Unit	%
KPI formula	$\frac{\sum Over\_ASL}{\sum \mathrm{ASL}} \times 100$
Traffica used counters	➔ **ASL** Counts the number of Egress Active Speech Level reliable measurements. Report Identification\Active Speech Level Reliable Measurement\ Counter Time Class TRAF MGW Voice Quality, 24 Hours, 30 Minutes ➔ **Over_ASL**

	Counts the number of Egress Active Speech Level reliable measurements where the Egress Active Speech Level is over the limit specified in the open node. Report Identification\Active Speech Level Reliable Measurement\ MGW Active Speech Level Upper Limit\Counter Time Class TRAF MGW Voice Quality, 24 Hours, 30 Minutes
Special Notes	- **ASL = 'Active Speech Level'** - **Egress -> Traffic direction out of a network element** - "If the termination point is connected, the Egress direction for one termination point is the ingress direction for the other termination point and vice-versa"

KPI name	**Frame Erasure Ratio**
Description	This KPI provides ratio of FER measurements that are over the limit
Unit	%
KPI formula	$\frac{\sum Over\_Link\_FER}{\sum \text{Link\_FER}} \times 100$
Traffica used counters	➔ **Link_FER** Counts the number of link FER reliable measurements for the network access. Report Identification\Link FER Reliable Measurement\Access Identification\ Counter Time Class TRAF MGW Voice Quality, 24 Hours, 30 Minutes ➔ **Over_Link_FER** Counts the number of link FER reliable measurements for the network access which exceeded the limit specified in the open node. Report Identification\Link FER Reliable Measurement\Access Identification\ MGW Access Link FER Upper Limit\Counter Time Class TRAF MGW Voice Quality, 24 Hours, 30 Minutes
Special Notes	**FER -> Frame Erasure Ratio: High Link FER values would mean connection problems which could translate into low voice quality.**

KPI name	**Packet Loss**
Description	This KPI provides the Packet Loss value per MGW
Unit	%

KPI formula	$\overline{Packet\_Loss}$
Traffica used counters	➔ **Packet_Loss** Sums the packet loss for each MGW and specific interface type. Report Identification\Packet Loss Reliable Measurement\User Plane Interface Vector\Network Element Id Vector\Packet Loss\Sum Time Class TRAF MGW Voice Quality, 24 Hours, 30 Minutes
Special Notes	- **Usually referred as IP Packet loss. However a more accurate description would be RTP Packet Loss, because IP/UDP has no sequence numbers and you can´t make difference between cases where IP packets aren´t sent or they are lost.**

6.2 SGSN

In this sub-section, real time counters related to SGSN will be studied. This study will be based on “Traffica Reference Guide for SGSN Direct Interface-dn05148836” ([31]).

This document lists all the Traffica counters that are related to SGSN.

6.2.1 Introduction

Summarizing, SGSN takes care of GPRS mobiles identification, registering to GPRS network and mobility management. SGSN also receives data from GPRS mobiles and sends data to the mobiles.

SGSN real time reports are generated in the following situations:

- PDP context activation (successful/unsuccessful)
- PDP context deactivation (successful/unsuccessful)
- Attaches (successful/unsuccessful)
- Detaches(successful/unsuccessful)
- Routing Area Updates
- SMS delivery (successful/unsuccessful)

These reports contain the following information:

- Subscriber IMSI and IMEI
- Subscriber location (LAC, RAC, Cell ID and SAC)
- An error cause code in case of an unsuccessful event
- PAPU (PAcket Processing Unit) ID

Besides this, in PDP context activation/deactivation, the Access Point Name (APN) and GGSN IP address are also presented.

6.2.2 Counters and KPIs

At this point, we will analyze the counters that are presented in the referred document, and try to find some real time KPIs that can be important to this work.

For this CCMA, there are three different time classes: 1 day, 24 hours and 30 minutes.

The Time Class 1 Day collects data cumulatively for one day. The time class is reset every midnight and counters are initialized. The counters are then updated cumulatively during the current day.

The Time Class 24 hours collects data hourly for the last 24 hours. There are separate counters for each hour for the last 24 hour period. Counters are reset and initialized at the beginning of each hour, for example at 12:00, 13:00, etc.

The Time Class 30 minutes collects data minutely for the last 30 minutes. There are separate counters for each minute for the last 30 minute period. Counters are reset and initialized every minute, for example at 12:01, 12:02, etc. For an example, at 12:00, there will be minutely counters available until 11:30.

KPIs to run @SGSN level

Following the previous approach, I'll try to establish a 'parallel' with the MSS related presented KPIs.

Considering the 'Call Setup' in MSS, it is safe to consider that the equivalent case for SGSN is the PDP context activation. With that information, the 'parallel' of 'Call Setup Success Ratio' may be defined as:

KPI name	**3G Successful PDP context activation Ratio**
Description	This KPI provides the ratio of successful PDP context activations
Unit	%
KPI formula	$\frac{\sum \text{Success\_PDP\_context}}{\sum \text{PDP\_context}} \times 100$
Trafficа used counters	➔ **Success_PDP_context** Counts the number of successful PDP Context Activations SGSN 3G Report\SGSN 3G Session Management Reports\PDP Context Activations\Successful\Counter Time Class 1 Day, 24 hours, 30 minutes ➔ **PDP_context** Counts the number of successful and unsuccessful PDP context activations SGSN 3G Report\SGSN 3G Session Management Reports\PDP Context Activations\Counter

	Time Class 1 Day, 24 hours, 30 minutes
Special Notes	

The parallel of ‘Total Calls’ and ‘Failure Calls’ can be obtained in the following way:

KPI name	**Total PDP context activations**
Description	This KPI provides the total number of PDP context activations
Unit	#
KPI formula	$\sum PDP\_context$
Traffica used counters	➔ **PDP_context** Counts the number of successful and unsuccessful PDP context activations SGSN 3G Report\SGSN 3G Session Management Reports\PDP Context Activations\Counter Time Class 1 Day, 24 hours, 30 minutes
Special Notes	

KPI name	**PDP context activation per error cause code**
Description	This KPI represents the number of PDP context activations per error causes
Unit	#
KPI formula	ECC_PDP
Traffica used counters	➔ **ECC_PDP** Counts all successful/unsuccessful PDP context activations for each Error Cause Code SGSN Report\PDP Context Activations\Error Cause Vector\Counter Time Class 1 Day, 24 hours, 30 minutes
Special Notes	According to [1], cause codes can be grouped in the following way: - 0x00 Success - MS initiated attach rejected by network - Accepted GPRS services only (CS-side fails) - MS initiated routing area update rejected by the network - Routing Area Update accepted for GPRS services only (CS-side fails) - MS initiated PDP context activation rejected by the network - MS initiated PDP context modification rejected by the network - Network requested PDP context deactivation

The attachment procedure represents an important step in data call setup procedures and that is why it is important to present a KPI able to translate the ratio of successful or unsuccessful attachments.

KPI name	**3G Unsuccessful Attachment Ratio**
Description	This KPI provides ratio of unsuccessful attachments
Unit	%
KPI formula	$$\frac{\sum 3G\_Failed\_Att}{\sum 3G\_Att} \times 100$$
Traffica used counters	➔ **3G_Failed_Att** Counts all unsuccessful 3G attaches SGSN Report\3G\Attaches\Unsuccessful\Counter Time Class 1 Day, 24 hours, 30 minutes ➔ **3G_Att** Counts all successful/unsuccessful 3G attaches SGSN Report\3G\Attaches\Counter Time Class 1 Day, 24 hours, 30 minutes
Special Notes	

The parallel of MSS 'Total Conversation Time' and 'Average Call Duration' may be related to data volume per SGSN. In the above referred document that has the SGSN related counters, there are counters that have data volume information per APN. Aggregating that information, it is possible to present a KPI like 'Data Volume per SGSN'.

KPI name	**Data Uplink**
Description	This KPI sums the uplink data volume per SGSN
Unit	Kbits
KPI formula	$$\sum Uplink$$
Traffica used counters	➔ **Uplink** Counts the data volume uplink for a specific APN SGSN 3G Report\Data Volume Available\APN Vector\Uplink Data Uplink\Sum Uplink Time Class 1 Day, 24 hours, 30 minutes

Special Notes	Data Volume per SGSN = Data Volume APN1 + Data Volume APN2 + … + Data Volume APNx
KPI name	**Data Downlink**
Description	This KPI sums the downlink data volume per SGSN
Unit	Kbits
KPI formula	$\sum Downlink$
Traffica used counters	➔ **Downlink** Counts the data volume Downlink for a specific APN SGSN 3G Report\Data Volume Available\APN Vector\Uplink Data Downlink\Sum Downlink Time Class 1 Day, 24 hours, 30 minutes
Special Notes	Data Volume per SGSN = Data Volume APN1 + Data Volume APN2 + … + Data Volume APNx

KPI name	**Data Call Dropped Ratio**
Description	This KPI represents the ratio of dropped calls
Unit	%
KPI formula	$\frac{\sum \mathrm{ECC\_PDP}}{\sum \mathrm{PDP\_context}}$
Traffica used counters	➔ **ECC_PDP** Counts all successful/unsuccessful PDP context activations for each Error Cause Code SGSN Report\PDP Context Activations\Error Cause Vector\Counter Time Class 1 Day, 24 hours, 30 minutes ➔ **PDP_context** Counts the number of successful and unsuccessful PDP context activations SGSN 3G Report\SGSN 3G Session Management Reports\PDP Context Activations\Counter Time Class 1 Day, 24 hours, 30 minutes
Special Notes	➔ In this case, the cause codes to be considered in 'ECC_PDP' are the ones that belong to group 'Network requested PDP context deactivation' (see Appendix C) ➔ Note that it doesn't correspond 100% to dropped calls, but in this context it can be considered an adequate parallel

6.3 Info per Mobile Type

6.3.1 Introduction

Besides the previously presented content, it would be interesting to provide information per user equipment type or, in other words, present some details per brand and model of user equipment. This is possible with Traffica, and this subject is the main focus of this sub-chapter.

Traffica provides lot of details of UE and type, which makes possible to see the “quality” of each model. Some failures may be caused by certain UE models and this dependency is not visible in performance measurements. Because of that, it may cause wrong indication of generic network problems [44].

Having these details per mobile type would lead to a more specific and model oriented management and it would be interesting to integrate this possibility in NPM. As an example, it would allow to know which handset works best in a certain network or isolate a given problem to know its origin (network issue or misbehaving handset model). Besides that, it has a “commercial” advantage because it is possible to know the most popular devices and each device flaws.

In Traffica, each model type has an identifier sequence number as we can see in the next example. In this case, the model is IPhone4 and the sequence is shown in “A Mobile Station” field.

Figure 51: Model type identifier in Traffica

This code is also known as TAC (Type allocation Code).

According to GSMA, Type Allocation Codes can be defined as [47]:

“A Type Allocation Code (TAC) is an 8 digit number allocated to 3GPP device manufacturers by the GSMA. Manufacturers use TAC to create a unique identifier for a mobile device known as International Mobile station Equipment Identity (IMEI). The IMEI is embedded into the devices at the time of manufacture. It must be implemented in such a way that it cannot be modified post manufacture. The purpose of the TAC code is to identify the device make and model. As such, different device models require different TAC”.

So, every handset has its own TAC and it is possible to see more examples in the next table:

Brand/Model	TAC
Apple / iPhone 5	01332700
Nokia / Lumia 625	35920605
HTC / One X	35918804
Samsung / Galaxy SIII	35226005
Samsung / Galaxy Note	35979504

Table 6: TAC examples [65]

In our case, we can use this TAC to group and filter the information, in order to have that same information per model type.

6.3.2 Counters and KPIs

According to "Traffica Reference Guide for 2G/3G Mobile Circuit Switched Core – dn98904766" ([13]), Traffica provides the following counters per mobile type:

RTT Report\Mobile Type Vector\ Counter (A side)

Explanation	Counts the number of calls and call attempts for each A subscriber mobile type
Time Class	TRAF 3G_Daily
Version	M13, M14, M15, M16, M16.1

RTT Report\Mobile Type Vector\Clear Code Vector\A Release\Counter (A Release)

Explanation	Counts the number of calls and call attempts that have ended in a certain clear code, release part is A subscriber and in which A subscriber has used a certain mobile type
Time Class	TRAF 3G_Daily
Version	M13, M14, M15, M16, M16.1

RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side)

Explanation	Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type
Time Class	TRAF 3G_Daily
Version	M13, M14, M15, M16, M16.1

RTT Report\Mobile Type Vector\Call Answered\Counter

Explanation	Counts the number of answered calls for each mobile type
Time Class	TRAF 3G_Daily
Version	M13, M14, M15, M16, M16.1

RTT Report\Mobile Type Vector\Call Answered\Call Dropped\Counter (Call Dropped)

Explanation	Counts the number of dropped calls for each mobile type
Time Class	TRAF 3G_Daily
Version	M13, M14, M15, M16, M16.1

With these counters, and following the approach that was used in the previous presented KPIs, it is possible to define some KPIs per mobile type that contain important information.

- **Time Class:**

  In the time Class **TRAF 3G_Daily**, the data is collected during the current day, starting from midnight when the counters are initialized, up to present moment.

- **KPIs per mobile type:**

KPI name	**CSR = Call Success Ratio per Mobile Type**
Description	This KPI provides the 3G call success ratio per mobile type.
Unit	%
KPI formula	$\frac{\sum \text{Normal Clearing}}{\sum \text{All\_Calls}} \times 100$
Trafficа used counters	➔ **All_Calls** Counts the number of calls and call attempts for each A subscriber mobile type RTT Report\Mobile Type Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1 ➔ **Normal Clearing**

	Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type. In this case we want to group the clear codes that are inside the interval [0000-03FF]. RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling.

KPI name	**CAR = Call Answered Ratio per mobile type**
Description	This KPI provides ratio of 3G calls that had been answered per mobile type.
Unit	%
KPI formula	$\frac{\sum Answ\_Calls}{\sum All\_Calls} \times 100$
Traffica used counters	→ **Answ_Calls** Counts the number of answered calls for each mobile type.

	RTT Report\Mobile Type Vector\Call Answered\Counter Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1 ➔ **All_Calls** Counts the number of all calls and call attempts for each A subscriber mobile type. RTT Report\Mobile Type Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**CCSR = Call Completion Success Ratio per mobile type**
Description	This KPI provides ratio of 3G calls that have ended with the CC 0 = "Normal end of the call", per mobile type
Unit	%
KPI formula	$\frac{\sum \text{Ended\_Calls}}{\sum \text{All\_Calls}} \times 100$
Traffica used counters	➔ **3G_Ended_Calls** Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type. In this case we consider only the clear code 0x00 RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1 ➔ **All_Calls** Counts the number of all calls and call attempts for each A subscriber mobile type.

	RTT Report\Mobile Type Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**Abnormal calls per mobile type**
Description	This KPI provides the number of abnormal calls calculated in a real time basis per mobile type.
Unit	#
KPI formula	$\sum \text{Int\_cong} + \sum \text{Ext\_Cong} + \sum \text{Subs\_Error}$
Traffica used counters	➔ **Int_Cong** **Internal Congestion Clear Codes** Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type. In this case we consider the clear codes in the interval [0400-07FF] RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1 ➔ **Ext_Cong** **External Congestion Clear Codes** Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type. In this case we consider the clear codes in the interval [0800-0BFF] RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1 ➔ **Subs_Error**

	Subscriber Errors Clear Codes Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type. In this case we consider the clear codes in the interval [0C00-0FFF] RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling.

KPI name	**3G Call Drop Ratio per mobile type**
Description	This KPI provides the Call drop ratio calculated in a real time basis per mobile type.
Unit	%
KPI formula	$\frac{\sum Drop\_Calls}{\sum Answ\_Calls} \times 100$
Traffica used counters	→ **Drop_Calls** Counts the number of dropped calls for each mobile type.

	RTT Report\Mobile Type Vector\Call Answered\Call Dropped\Counter (Call Dropped) Time Class TRAF 3G_Daily, Version M13, M14, M15, M16, M16.1 ➔ **Answ_Calls** Counts the number of answered calls for each mobile type. RTT Report\Mobile Type Vector\Call Answered\Counter Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**3G Total Calls per mobile type**
Description	This KPI provides the total number of 3G calls in a real time basis per mobile type
Unit	#
KPI formula	$\sum All\_Calls$
Traffica used counters	➔ **All_Calls** Counts the number of all calls and call attempts for each A subscriber mobile type. RTT Report\Mobile Type Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	

KPI name	**Success Calls per mobile type**
Description	This KPI provides the number of success calls calculated in a real time basis.
Unit	#
KPI formula	$\sum \text{Normal\_Clearing}$
Traffica used counters	

	➔ **Normal Clearing** Counts the number of calls and call attempts that have ended in a certain clear code and in which A subscriber has used a certain mobile type. In this case we want to group the clear codes that are inside the interval [0000-03FF]. RTT Report\Mobile Type Vector\Clear Code Vector\Counter (A side) Time Class TRAF 3G_Daily Version M13, M14, M15, M16, M16.1
Special Notes	Group of Clear Codes: **0000H - 03FFH → Normal clearing** **0400H - 07FFH → Internal congestion** Includes the cases in which the call or call set-up is interrupted due to a malfunction in the own exchange. Primarily, this class contains clear codes associated with communication between the various computer units and program blocks of an exchange and those associated with the handling of files. **0800H - 0BFFH → External congestion** Includes all cases in which a call or a call set-up is interrupted by a malfunction outside the exchange in question. Primarily, this class contains clear codes associated with inter-exchange connections. **0C00H - 0FFFH → Subscriber errors** Includes all cases in which a call or a call set-up is interrupted due to a subscriber error, due to a failure in the subscriber's equipment or due to faulty subscriber signaling.

6.4 Network Elements Integration

With the previously presented KPIs, it is possible to have a global idea about the entire Core Network, and that is why it is important to present this information in a real time basis, along with long term data that “exists” in NPM. Note that the selected (MSS) and the presented (other cases) KPIs aren´t the only “integrable” KPIs, but as we want real time data, not all the data can be “passed” to NPM, and a selection of the most important data has to be made.

The next figure illustrates a possible basic integration with all of these elements.

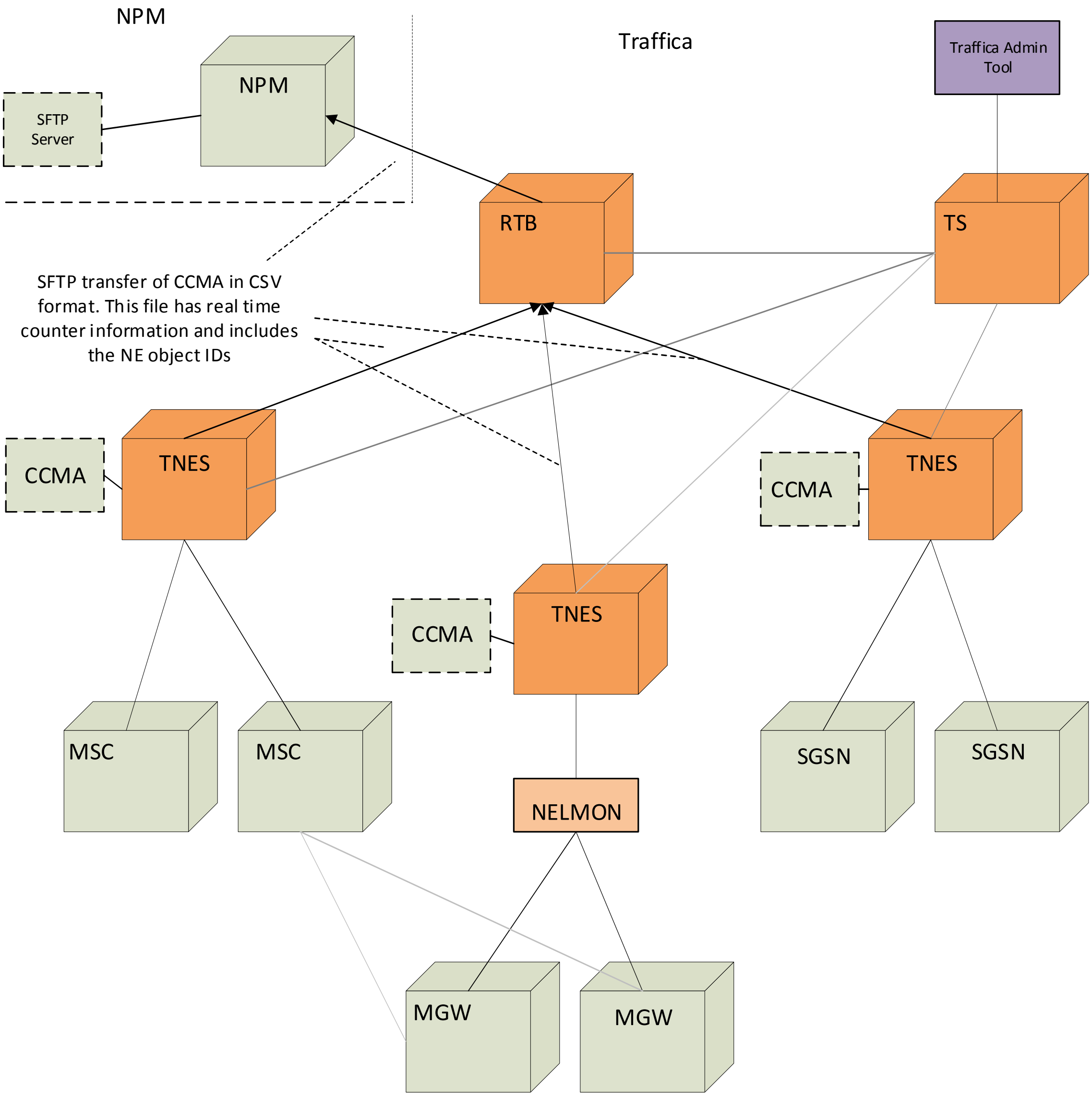


Figure 52: MSS, MGW and SGSN basic integration (drawn by the author)

One of the major issues of this type of integration is related to NEs ID, since they are different in Traffica and in NPM. MGW constitutes an even bigger challenge because it is possible to have several MGWs connected to the same Nelmon.

In this specific case, in order to have the MGW ID, it is mandatory to understand the relation between Nelmon and MGW. According to [42], to start the Nelmon application, the MGW ID number should be passed as a parameter. This way, we know which MGWs are connected to Nelmon and it is possible to pass those IDs in CCMA, and thus, know the MGW IDs in NPM.

The Element information is printed like:

ElemId	Element Name	Cnumber	IPoA Net Address	Control Type	Control Status	PID
13	MGW1	15770	11.99.10.16	auto	CTRL_ACTIVE	3710
16	MGW2	12345	11.99.10.0	manual	CTRL_ACTIVE	3434

Figure 53: Nelmon and MGW ID [42]

In the MSS and SGSN, the IDs can also be included in CCMA, and it shouldn´t be much complicated to implement.

In the next chapter, I'll try to present a proof of concept in order to clarify and explain some of those referred challenges, and to analyze the many benefits that this integration can bring.

7. PoC Implementation

7.1 Fundamental Concepts

Taking advantage of figure 52, and since this PoC will only cover the MSS, this integration schema is the following (note that in this case, RTB won't be considered because it is not a mandatory element).

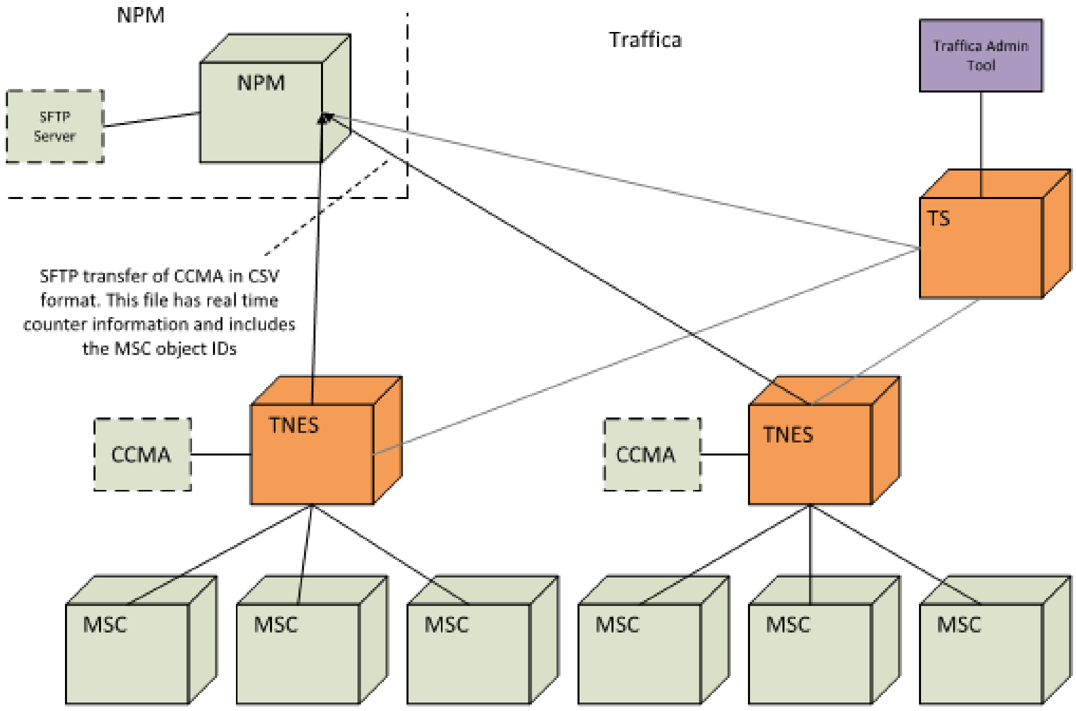


Figure 54: NPM-Traffica Basic Operation (drawn by the author)

Hereupon, it is really important to have some important concepts in mind.

<u>Remembering Traffica Operation</u>:

As we already know, Traffica is a system for collecting, storing, post-processing and analyzing event-based data from a network.

Traffica system consists of three types of physical servers: Traffica Network Element Server (TNES), Traffica Server (TS) and Real Time Broker (RTB). When an event occurs in NE, it sends a Real Time Traffic Report (RTT Report) to TNES with information related to the event.

When TNES receives a new RTT Report, traffica.exe identifies and stores the data into intermediate data buffer called Internal Data Structure (IDS). Traffica.exe reads the data from IDS and writes the data into database and updates Traffica CCMA counters based on it.

Remembering CCMA export operation:

This functionality is part of RTT Server component and allows exporting counter values from Traffica CCMA in csv format. CCMA Export Configuration defines which counters/vectors are to be exported. It is possible to define individual CCMA paths to be exported, or alternatively, a whole time class, in which case, all counters and vectors that have an export label defined for them are exported.

This export is triggered by a time class reset. When one time slice is complete and a time class reset occurs, the data from complete time slice is immediately exported into pairs of .ctr and .dat files.

When a new control file is found for TNES, that .ctr file and the corresponding .dat file are transferred into defined FTP/SFTP server. After successful transfer, both files are deleted from TNES.

The next two figures illustrate this procedure.

The first one represents an overview of this integration and underlines the fact that some kind of intermediate processing is needed, like KPI calculation, for an example.

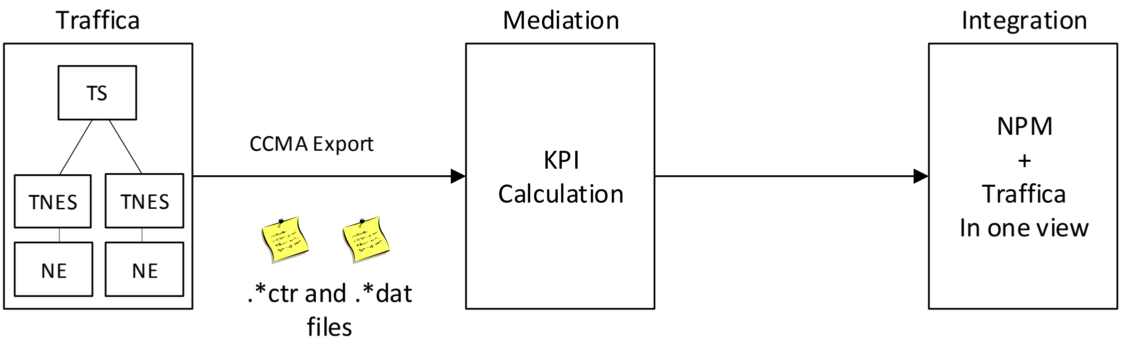


Figure 55: Integration Scheme (drawn by the author)

The next figure consists in a “magnified” view of NE and TNES connection:

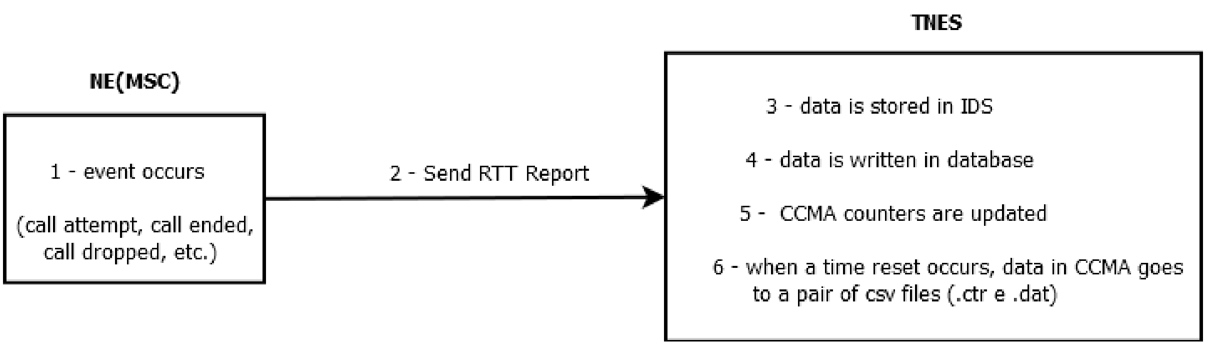


Figure 56: NE and TNES co-operation (drawn by the author)

With this operation in mind, the next step is to study the CSV files in more detail, and then implement a Proof of Concept in order to present NPM and Traffica data in one view. The goal is to have a simple and intuitive way to display both data types, allowing a really complete overview of the entire network.

Note that this proof of concept will be MSS related and therefore, only MSS related counters and KPIs will be considered.

7.2 Pre-Implementation Study

7.2.1 CSV Files Analysis

In CCMA Export the data is exported in a pair of CSV files. These types of files are very flexible and thus, can assume different forms in terms of structure. As this is a real time application, time is a mandatory issue and can differ based on those files structure so, it is important to study some of those possible formats that can be used in this implementation. In this case, it is important to balance the amount of data to be transmitted, with the complexity involved in processing that same data, because the total time will depend on delivery time and processing time.

For this study, take the following information for an example:

Used/Transmitted Counters/KPIs:

- CALL_SETUP_COUNT
- CALL_SETUP_FAILURE_COUNT
- CALL_DURATION_SUM
- CALL_ANSWERED_COUNT
- CALL_DROPPED_COUNT
- SIGNALLING_PHASE_CALL_COUNT_per_CC_SIGNALING_PHASE
- RINGING_PHASE_CALL_COUNT_per_CC_RINGING_PHASE
- SPEECH_PHASE_CALL_COUNT_per_CC_SPEECH_PHASE

Take into consideration 2 MSCs with IDs 0 and 3 (called DATA_SOURCE_ID) and that we want to know the clear codes id and the number of occurrences of those same clear codes per phase of the call.

The “standard” csv files would be something like the ones that are presented next.

First, let’s take a look at .ctr file:

```
LOAD DATA
INFILE 'trafCCMAE_TRAF_MSS_NPM_MSS_CND41107QK_20140915144400_20140915144400_0-UTCB20140915114400-UTCE20140915114400.dat'
INTO TABLE "TRAFFICA"."TRAF_MSS_NPM_MSS"
FIELDS TERMINATED BY ','
OPTIONALLY ENCLOSED BY '"'
(
        "Report_Time" TIMESTAMP NULLIF BLANKS,
        "DATA_SOURCE_ID" UINT32 NULLIF BLANKS,
        "CALL_SETUP_COUNT" UINT32 NULLIF BLANKS,
        "CALL_SETUP_FAILURE_COUNT" UINT32 NULLIF BLANKS,
        "CALL_ANSWERED_COUNT" UINT32 NULLIF BLANKS,
        "CALL_DURATION_SUM" DOUBLE NULLIF BLANKS,
        "CALL_DROPPED_COUNT" UINT32 NULLIF BLANKS,
        "CC_SIGNALLING_PHASE" UINT32 NULLIF BLANKS,
        "CC_SIGNALLING_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS,
        "CC_RINGING_PHASE" UINT32 NULLIF BLANKS,
        "CC_RINGING_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS,
        "CC_SPEECH_PHASE" UINT32 NULLIF BLANKS,
        "CC_SPEECH_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS
)
```

Date and Time

NE id

clear code id in signaling phase

number of occurrences

Figure 57: “Standard" .ctr file

The parameter after “INFILE” keyword (highlighted in yellow) describes the respective .dat file name.

The corresponding .dat file is the following:

```
2014-09-15 14:44:00,3,45,5,37,5.220290E+003,1,,,,,,
2014-09-15 14:44:00,0,29,2,22,3.921720E+003,1,,,,,,

2014-09-15 14:44:00,3,,,,,,5,2,,,,
2014-09-15 14:44:00,3,,,,,,778,1,,,,
2014-09-15 14:44:00,3,,,,,,21,1,,,,
2014-09-15 14:44:00,3,,,,,,779,1,,,,
2014-09-15 14:44:00,0,,,,,,778,1,,,,
2014-09-15 14:44:00,0,,,,,,21,1,,,,
2014-09-15 14:44:00,3,,,,,,,,779,2,,
2014-09-15 14:44:00,3,,,,,,,,6,1,,
2014-09-15 14:44:00,0,,,,,,,,518,1,,
2014-09-15 14:44:00,0,,,,,,,,779,4,,
2014-09-15 14:44:00,3,,,,,,,,,,0,36
2014-09-15 14:44:00,3,,,,,,,,,,21,1
2014-09-15 14:44:00,0,,,,,,,,,,0,21
2014-09-15 14:44:00,0,,,,,,,,,,2835,1
```

Clear Code Analysis per phase

Date and Time

NE Id

Figure 58: "Standard" .dat file

In this approach, the .dat file is “divided” in two parts. The first two rows are one part (above the red line) and the remaining rows are the other part that has clear code based information (below the red line).

To simplify this analysis, a matrix representation of this file will be used.
The notation to be used is the following:

$\left\lfloor A_{i,j} \right\rfloor$, where i represents the row index and j represents the column index.

With this notation, the “standard” .dat file can be transformed in the following 16×13 matrix:

$$\begin{bmatrix}
A_{1,1} & A_{1,2} & A_{1,3} & A_{1,4} & A_{1,5} & A_{1,6} & A_{1,7} & A_{1,8} & A_{1,9} & A_{1,10} & A_{1,11} & A_{1,12} & A_{1,13} \\
A_{2,1} & A_{2,2} & A_{2,3} & A_{2,4} & A_{2,5} & A_{2,6} & A_{2,7} & A_{2,8} & A_{2,9} & A_{2,10} & A_{2,11} & A_{2,12} & A_{2,13} \\
A_{3,1} & A_{3,2} & A_{3,3} & A_{3,3} & A_{3,5} & A_{3,6} & A_{3,7} & A_{3,8} & A_{3,9} & A_{3,10} & A_{3,11} & A_{3,12} & A_{3,13} \\
A_{4,1} & A_{4,2} & A_{4,3} & A_{4,4} & A_{4,5} & A_{4,6} & A_{4,7} & A_{4,8} & A_{4,9} & A_{4,10} & A_{4,11} & A_{4,12} & A_{4,13} \\
A_{5,1} & A_{5,2} & A_{5,3} & A_{5,4} & A_{5,5} & A_{5,6} & A_{5,7} & A_{5,8} & A_{5,9} & A_{5,10} & A_{5,11} & A_{5,12} & A_{5,13} \\
A_{6,1} & A_{6,2} & A_{6,3} & A_{6,4} & A_{6,5} & A_{6,6} & A_{6,7} & A_{6,8} & A_{6,9} & A_{6,10} & A_{6,11} & A_{6,12} & A_{6,13} \\
A_{7,1} & A_{7,2} & A_{7,3} & A_{7,4} & A_{7,5} & A_{7,6} & A_{7,7} & A_{7,8} & A_{7,9} & A_{7,10} & A_{7,11} & A_{7,12} & A_{7,13} \\
A_{8,1} & A_{8,2} & A_{8,3} & A_{8,4} & A_{8,5} & A_{8,6} & A_{8,7} & A_{8,8} & A_{8,9} & A_{8,10} & A_{8,11} & A_{8,12} & A_{8,13} \\
A_{9,1} & A_{9,2} & A_{9,3} & A_{9,4} & A_{9,5} & A_{9,6} & A_{9,7} & A_{9,8} & A_{9,9} & A_{9,10} & A_{9,11} & A_{9,12} & A_{9,13} \\
A_{10,1} & A_{10,2} & A_{10,3} & A_{10,4} & A_{10,5} & A_{10,6} & A_{10,7} & A_{10,8} & A_{10,9} & A_{10,10} & A_{10,11} & A_{10,12} & A_{10,13} \\
A_{11,1} & A_{11,2} & A_{11,3} & A_{11,4} & A_{11,5} & A_{11,6} & A_{11,7} & A_{11,8} & A_{11,9} & A_{11,10} & A_{11,11} & A_{11,12} & A_{11,13} \\
A_{12,1} & A_{12,2} & A_{12,3} & A_{12,4} & A_{12,5} & A_{12,6} & A_{12,7} & A_{12,8} & A_{12,9} & A_{12,10} & A_{12,11} & A_{12,12} & A_{12,13} \\
A_{13,1} & A_{13,2} & A_{13,3} & A_{13,4} & A_{13,5} & A_{13,6} & A_{13,7} & A_{13,8} & A_{13,9} & A_{13,10} & A_{13,11} & A_{13,12} & A_{13,13} \\
A_{14,1} & A_{14,2} & A_{14,3} & A_{14,4} & A_{14,5} & A_{14,6} & A_{14,7} & A_{14,8} & A_{14,9} & A_{14,10} & A_{14,11} & A_{14,12} & A_{14,13} \\
A_{15,1} & A_{15,2} & A_{15,3} & A_{15,4} & A_{15,5} & A_{15,6} & A_{15,7} & A_{15,8} & A_{15,9} & A_{15,10} & A_{15,11} & A_{15,12} & A_{15,13} \\
A_{16,1} & A_{16,2} & A_{16,3} & A_{16,4} & A_{16,5} & A_{16,6} & A_{16,7} & A_{16,8} & A_{16,9} & A_{16,10} & A_{16,11} & A_{16,12} & A_{16,13}
\end{bmatrix}$$

Where the elements represent the following:

$\left\lfloor A_{i,1} \right\rfloor$ = Report Time , for i $\in$ [1,16]

$\left\lfloor A_{i,2} \right\rfloor$ = NE Id , for i $\in$ [1,16]

$\left\lfloor A_{i,3} \right\rfloor$ = Call Setup Count , for i $\in$ [1,2]

$\left\lfloor A_{i,4} \right\rfloor$ = Call Setup Failure Count , for i $\in$ [1,2]

$\left\lfloor A_{i,5} \right\rfloor$ = Call Answered Count , for i $\in$ [1,2]

$\lfloor A_{i,6} \rfloor$ = Call Duration Sum , for i $\in$ [1,2]

$\lfloor A_{i,7} \rfloor$ = Call Dropped Count , for i $\in$ [1,2]

In this particular case, the first row of .dat file contains the following information:

- Report Time = 2014-09-15 14:44:00
- Data Source Id = 3
- Call Setup Count = 45
- Call Setup Failure Count = 5
- Call Answered Count = 37
- Call Duration Sum = 5.220290E+003
- Call Dropped Count = 1

And the second row of .dat file contains the following information:

- Report Time = 2014-09-15 14:44:00
- Data Source Id = 0
- Call Setup Count = 29
- Call Setup Failure Count = 2
- Call Answered Count = 22
- Call Duration Sum = 3.921720E+003
- Call Dropped Count = 1

These first two rows represent the “overview” of the situation, and the remaining rows have more detailed information.

If $\lfloor A_{i,8} \rfloor$, for i $\in$ [3,16] ≠ ‘null’ , it means that the clear code represented in that field occurred a certain number of times in signaling phase. The number of occurrences is given by $\lfloor A_{i,9} \rfloor$.

The analysis is similar for the other call phases:

If $\lfloor A_{i,10} \rfloor$, for i $\in$ [3,16] ≠ ‘null’ , it means that the clear code represented in that field occurred a certain number of times in ringing phase. The number of occurrences is given by $\lfloor A_{i,11} \rfloor$.

If $\lfloor A_{i,12} \rfloor$, for i $\in$ [3,16] ≠ ‘null’ , it means that the clear code represented in that field occurred a certain number of times in speech phase. The number of occurrences is given by $\lfloor A_{i,13} \rfloor$.

For Signaling Phase and Data Source Id = 3, we have the following information:

- Clear Code 5 occurred 2 times
- Clear Code 778 occurred 1 time
- Clear Code 21 occurred 1 time
- Clear Code 779 occurred 1 time

For Signaling Phase and Data Source Id = 0:

- Clear Code 778 occurred 1 time
- Clear Code 21 occurred 1 time

For Ringing Phase and Data Source Id = 3:

- Clear Code 779 occurred 2 times
- Clear Code 6 occurred 1 time

For Ringing Phase and Data Source Id = 0:

- Clear Code 518 occurred 1 time
- Clear Code 779 occurred 4 times

For Speech Phase and Data Source Id = 3:

- Clear Code 0 occurred 36 times
- Clear Code 21 occurred 1 time

For Speech Phase and Data Source Id = 0:

- Clear Code 0 occurred 21 times
- Clear Code 2835 occurred 1 time

An easy way to confirm this information and check if everything is working right is the following:

- The number of setup count needs to be the same as the sum of all the clear codes occurrences, for the same NE
- The number of setup failures needs to be equal to the sum of the clear codes occurrences in the signaling phase, for the same NE
- The number of Answered Calls has to be equal to the number of occurrences of clear codes in the speech phase, for the same NE
- The number of dropped calls needs to be equal to ((all clear codes in the speech phase)-(number of occurrences of clear code 0))

In this case, everything is ok and we have the data that is needed to “create” and integrate some important KPIs in NPM. But is this the most appropriate way to transfer data from Traffica? Is this the best structure to use in .dat files? Is it really necessary to “reserve” 6 fields to clear code analysis when only two are used at the same time?

Next, we'll present some alternatives to this approach and we'll try to conclude what is the best structure to be used, having in mind the simplicity, the time of transmission and the processing of the information.

The first alternative consists in turning the 6 fields that make part of clear code analysis in 3 fields, maintaining the remaining structure. In this case, we would have one field to represent the call phase, other to represent the clear code Id and another one to represent the number of occurrences. The field "CC PHASE" would have three possible values: 1 for signaling phase, 2 for ringing phase and 3 for speech phase.

The "new" .ctr and .dat files would be a little different as it is possible to observe in the next figures.

First, the .ctr file:

```
LOAD DATA
INFILE 'trafCCMAE_TRAF_MSS_NPM_MSS_CND41107QK_20140915144400_20140915144400_0-UTCB20140915114400-UTCE20140915114400.dat'
INTO TABLE "TRAFFICA"."TRAF_MSS_NPM_MSS"
FIELDS TERMINATED BY ','
OPTIONALLY ENCLOSED BY '"'
(
        "Report_Time" TIMESTAMP NULLIF BLANKS,
        "DATA_SOURCE_ID" UINT32 NULLIF BLANKS,
        "CALL_SETUP_COUNT" UINT32 NULLIF BLANKS,
        "CALL_SETUP_FAILURE_COUNT" UINT32 NULLIF BLANKS,
        "CALL_ANSWERED_COUNT" UINT32 NULLIF BLANKS,
        "CALL_DURATION_SUM" DOUBLE NULLIF BLANKS,
        "CALL_DROPPED_COUNT" UINT32 NULLIF BLANKS,
        "CC_PHASE" UINT32 NULLIF BLANKS,
        "CC_ID" UINT32 NULLIF BLANKS,
        "CC_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS,
        )
```

Figure 59: Other .ctr file possibility (Method 2)

As it is possible to observe, the clear code related fields reduced from 6 to 3, and the .dat file would have the following structure:

```
2014-09-15 14:44:00,3,45,5,37,5.220290E+003,1,,,
2014-09-15 14:44:00,0,29,2,22,3.921720E+003,1,,,

2014-09-15 14:44:00,3,,,,,,1,5,2
2014-09-15 14:44:00,3,,,,,,1,778,1
2014-09-15 14:44:00,3,,,,,,1,21,1
2014-09-15 14:44:00,3,,,,,,1,779,1
2014-09-15 14:44:00,0,,,,,,1,778,1
2014-09-15 14:44:00,0,,,,,,1,21,1

2014-09-15 14:44:00,3,,,,,,2,779,2
2014-09-15 14:44:00,3,,,,,,2,6,1
2014-09-15 14:44:00,0,,,,,,2,518,1
2014-09-15 14:44:00,0,,,,,,2,779,4

2014-09-15 14:44:00,3,,,,,,3,0,36
2014-09-15 14:44:00,3,,,,,,3,21,1
2014-09-15 14:44:00,0,,,,,,3,0,21
2014-09-15 14:44:00,0,,,,,,3,2835,1
```

Signaling phase

Ringing phase

Speech phase

call phase

Figure 60: Other .dat file possibility (Method 2)

It is the same information presented in a similar way, but this little modification may make a difference in transmission time and processing time. The file has fewer fields, which may lead to a lighter file and faster processing. However, on the other hand, it would be necessary some kind of “intelligence” to associate the numbers (1, 2, 3) to the stage of the call, which would in theory, increase the processing time again.

Assuming the matrix representation, this would be a 16×10 matrix and $\lfloor A_{i,8} \rfloor$ would represent the call phase, $\lfloor A_{i,9} \rfloor$ would have the clear code id and $\lfloor A_{i,10} \rfloor$ the number of occurrences of that clear code.

Another possibility is to have just one line of data per time period and NE id.

The .ctr file would be similar to the one presented in the previous approach, but the .dat file would only have one line per NE and Time period, which constitutes a huge difference.

Next, it is possible to see an example of the .dat file.

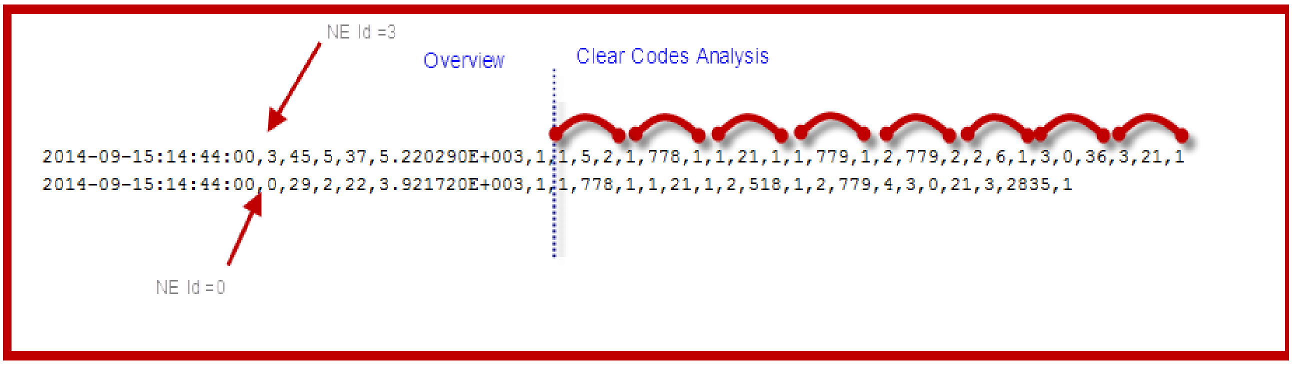


Figure 61: Other .dat file possibility (Method 3)

With this approach, less amount of data would have to be transferred from Traffica to NPM and we would only have one line per NE id and time. The clear code section (red arcs) would be a flexible structure that would have as many groups of triplets as NE provided clear codes.

For this specific example, it would be a 2×30 matrix.

The overview part occurs for $\lfloor A_{i,j} \rfloor$ where j $\in$ [1,7] and the clear code analysis is for j>7.

This case would decrease the file size, optimizing the transmission time, but it might cause some alterations in the processing time.

To analyze these questions, I made a simple study using Java programming language and Eclipse IDE. Manipulating the .dat files and then importing and parsing them for the three presented possibilities, it is possible to reach some conclusions.

For this example, in order to turn this study more realistic, I considered 6 MSS and around 200 clear codes occurrences per MSS per minute: 50 clear codes in signaling phase, 50 clear codes in the ringing phase, and 100 clear codes in the speech phase.

Hence, because of each .dat file characteristics, the approach has to be different for each case. The major differences are in the parse of the clear codes, as it is possible to observe in the next blocks diagrams that "translate" the programming code regarding the clear codes analysis.

"Standard" Method

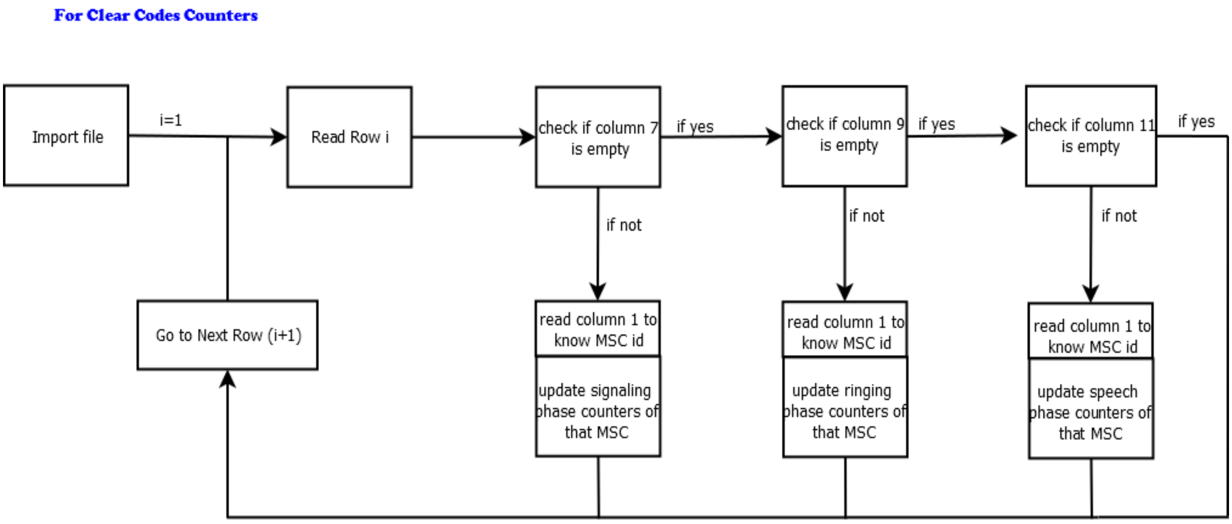


Figure 62: "Standard" method - Programming code representation (drawn by the author)

2^{nd} Method

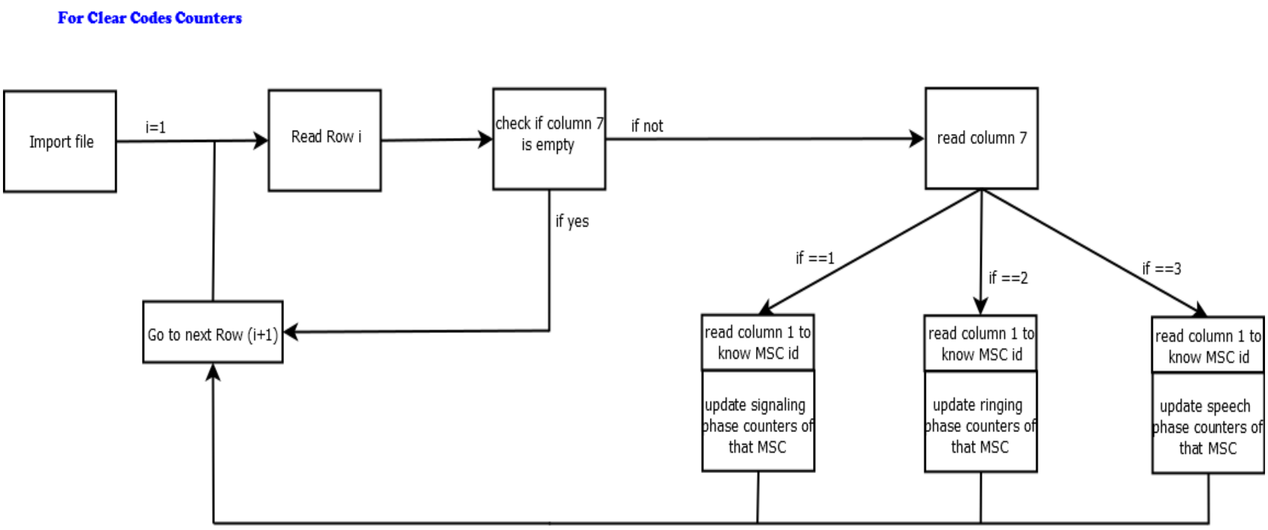


Figure 63: 2nd method - Programming code representation (drawn by the author)

3rd Method

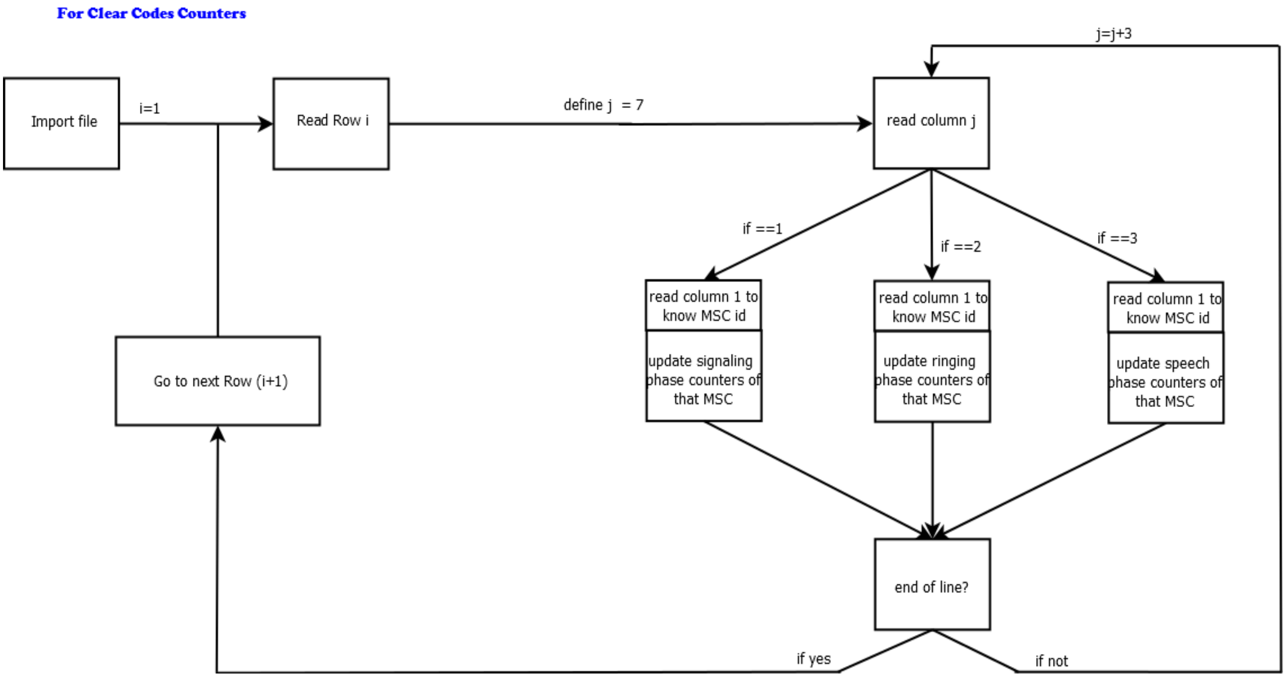


Figure 64: 3rd method - Programming code representation (drawn by the author)

Note that in all of these cases, the 'update signaling/ringing/speech phase counters of that MSC' stage consists of:

- Read CC Id
- Read number of occurrences of that clear code in the respective phase
- Update total number of occurrences per call phase

Besides the presented differences in clear codes section analysis, the 3rd method has another important advantage: there is no need to check if the fields are empty because in this case there are no empty rows/fields. In the "standard" and 2nd method that is not possible because in the overview part, the clear codes part is empty and vice-versa. In these cases, it is necessary to check almost every row to know if they are empty or not before processing the information.

Dismissing the prints because only the processing really matters, I obtained the following results for the different .dat files:

	"Standard"	**Method 2**	**Method 3**
Processing Time	8.66 ms	7.64 ms	3.09 ms
File Size (approximately)	31KB	28KB	6KB

Table 7: Obtained results for the 3 different approaches

In order to analyze these results, I'll present two possible scenarios where the impact of file size and processing time regarding the total time involved in this process might be seen.

Note that the total time involved in this process is:

$$\mathrm{Total\_Time} = \mathrm{Packet\_Delivery\_Time} + \mathrm{Processing\_time} \;,$$

where

$$Packet\_Delivery\_Time = Transmission\_Time + Propagation\_Delay$$

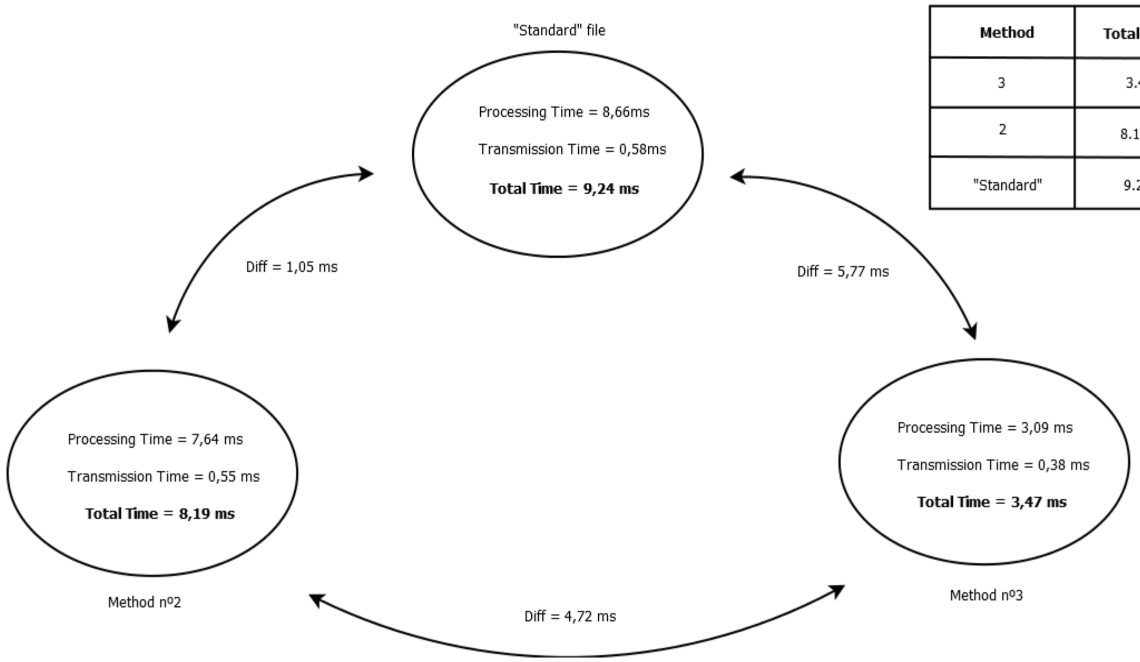
$$Transmission\_Time = File\_Size \,/\, Bit\ Rate$$

and

$$Propagation\_Delay = distance \,/\, c \qquad \text{, for optical fiber}$$

<u>1st Scenario</u>

Consider that Traffica and NPM are close (about 100 Km) and connected by optical fiber with transmission rate of 1Gbps. This is a typical situation of an operator that has Traffica and NPM operating in the same country. Using the presented formulas, the obtained results are:



Methods Ranking

Method	Total Time
3	3.47 ms
2	8.19 ms
"Standard"	9.24 ms

Figure 65: Comparison of the different methods times in the 1st scenario

2^{nd} Scenario

Consider that Traffica and NPM are in different countries “separated” for 2000 Km and the optical fiber network has a transmission rate of 155 Mbps. This scenario may represent a situation where the operator has Traffica in one country (let´s take Italy for an example) and needs to send the data to be processed in NPM in Lisbon.

Again, using the same logic and the referred formulas:

Methods Ranking

Method	Total Time
3	16.39 ms
2	22.09 ms
"Standard"	23.26 ms

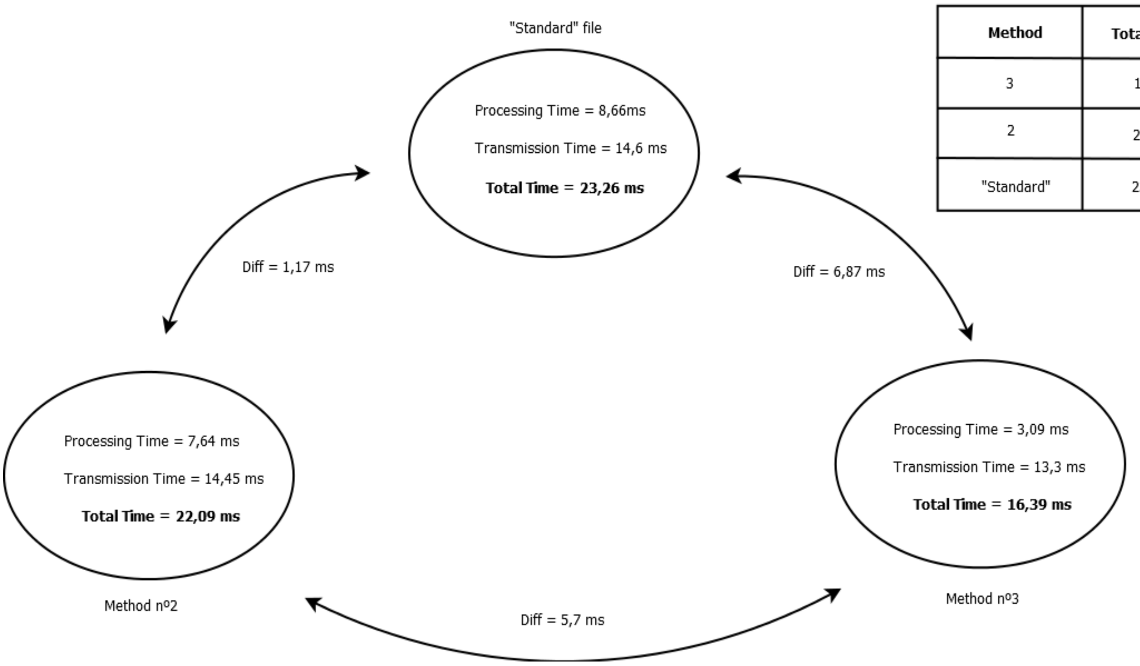


Figure 66: Comparison of the different methods times in the 2nd scenario

This is an unexpected result, especially because the processing of the third method is much faster than the other two. It may be related to the previously mentioned advantage and/or be related to the reduced number of lines of the file.

Considering these results, the use of the third type of .dat file would be very beneficial because it is the quickest and the lightest, and presents the best performance in both scenarios.

Although this is a very “homemade” test, the results are interesting and it might be worth to study the .ctr and .dat files structure in more detail in future work.

For now, the structure to be considered is the “standard” one.

7.2.2 OMeS

OMeS (Open Measurement Standard) Description [60]:

- Is an XML based measurement file format for exchanging performance measurement results between network elements and network management systems
- Combination of the data model and the physical representation of the data
- Unified way of modeling and representing measurement results. OMeS is designed to be generic enough to be used in telecom and other fields where measurements are used
- Provides a single, conceptual framework for describing measurement results of almost any kind
- Owned by Nokia

The next figure illustrates the way OMeS is related to the previously studied concepts and helps in the understanding of its importance.

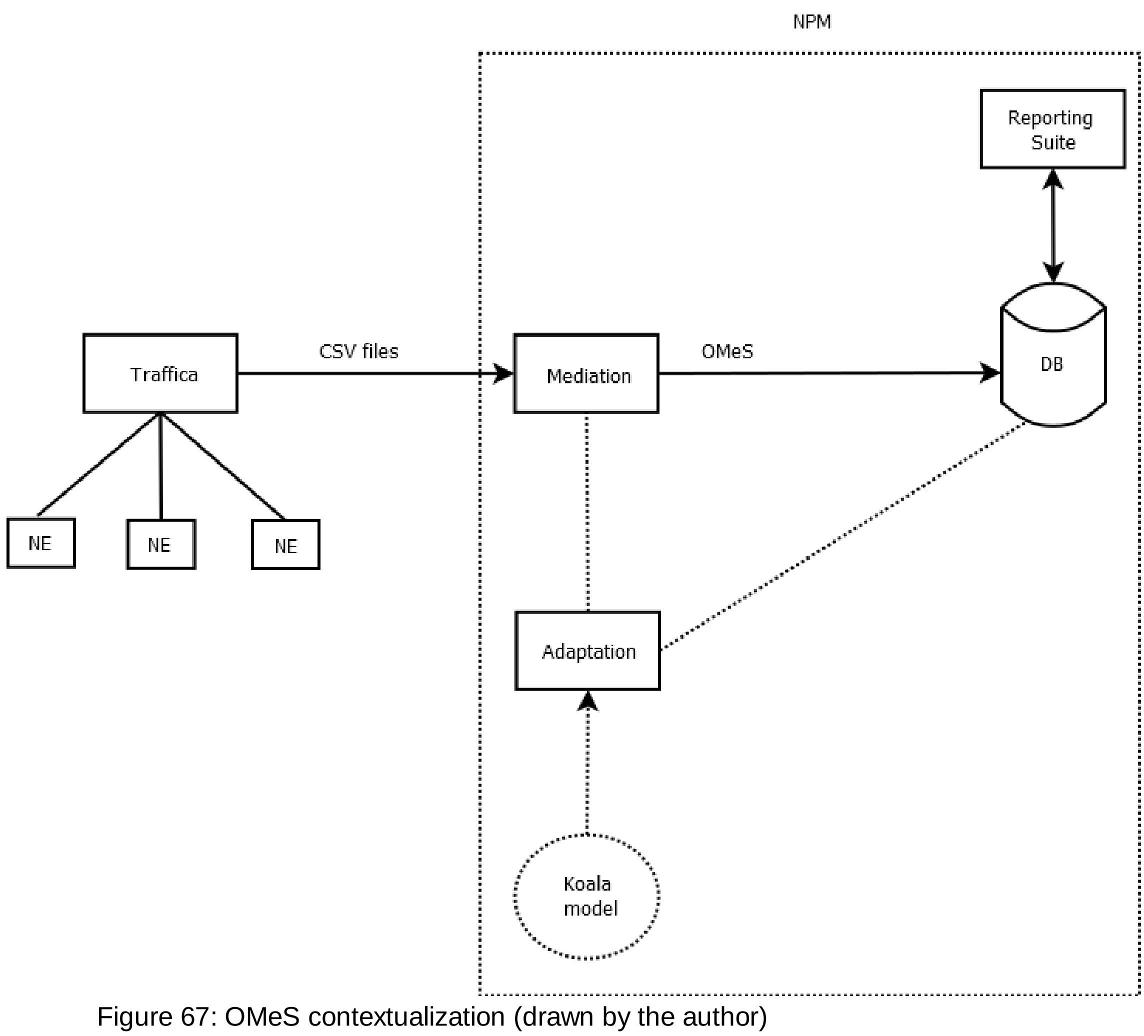


Figure 67: OMeS contextualization (drawn by the author)

Until this point, it was considered that Traffica and NPM were directly connected, never considering the intermediate steps of this process. In the above figure it is possible to observe those steps and conclude that this connection is not that simple.

The CSV files that come from Traffica are processed in a mediation layer and are “transformed” in OMeS files. The Koala model is the basis of this process and it is responsible for the definition of the model of these files as well as the model of the Database where those files will be stored. It is mandatory that the two parts are in concordance to avoid conflicts and loss of information. Then, NPM Reporting Suite can access the database, process the data and present it in the most appropriate way.

Although ‘Mediation’ and ‘Adaptation’ processes are very important processes, they will not be studied in this work because that study lies outside of this dissertation main goals.
For this PoC implementation, that step should be considered “invisible”.
To solve this problem, I will start with a “handcrafted” OMeS file simulating received data from the CSV files. This OMeS file will be presented in further section.

7.3 *Actual Implementation*

7.3.1 Counters and KPIs

First of all, let´s clarify the Traffica counters that will be used and the wanted resulting KPIs:

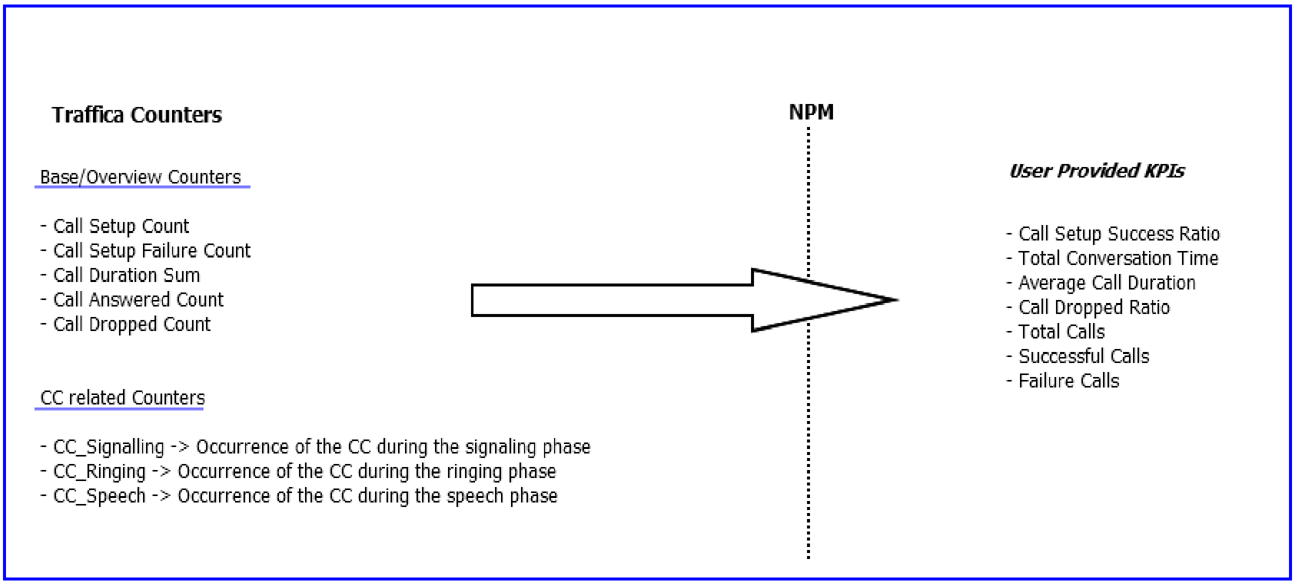


Figure 68: Wanted Counters and KPIs (drawn by the author)

All of these counters were part of the previously presented CSV files and were also presented in previous sections, as well as the wanted KPIs.

After this clarification, it is possible to initiate the PoC implementation.

7.3.2 Counters Definition

Considering the studied situation in CSV files analysis section, it is possible to present a parallel between the CSV files and the corresponding OMeS file.

Excepting the Report time and the MSC Id (these fields don´t match), the next figure presents the CSV files equivalent.

Note that the information in OMeS file corresponds to MSC 3 in CSV files.

.*ctr file

```
LOAD DATA
INFILE 'trafCCMAE_TRAF_MSS_NPM_MSS_CND41107QK_20140915144400_20140915144400_0-UTCB20140915114400-UTCE20140915114400.dat'
INTO TABLE "TRAFFICA"."TRAF_MSS_NPM_MSS"
FIELDS TERMINATED BY ','
OPTIONALLY ENCLOSED BY '"'
(
        "Report_Time" TIMESTAMP NULLIF BLANKS,
        "DATA_SOURCE_ID" UINT32 NULLIF BLANKS,
        "CALL_SETUP_COUNT" UINT32 NULLIF BLANKS,
        "CALL_SETUP_FAILURE_COUNT" UINT32 NULLIF BLANKS,
        "CALL_ANSWERED_COUNT" UINT32 NULLIF BLANKS,
        "CALL_DURATION_SUM" DOUBLE NULLIF BLANKS,
        "CALL_DROPPED_COUNT" UINT32 NULLIF BLANKS,
        "CC_SIGNALLING_PHASE" UINT32 NULLIF BLANKS,
        "CC_SIGNALLING_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS,
        "CC_RINGING_PHASE" UINT32 NULLIF BLANKS,
        "CC_RINGING_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS,
        "CC_SPEECH_PHASE" UINT32 NULLIF BLANKS,
        "CC_SPEECH_PHASE_CALL_COUNT" UINT32 NULLIF BLANKS
)
```

.*dat file

```
2014-09-15 14:44:00,3,45,5,37,5.220290E+003,1,,,,,,
2014-09-15 14:44:00,0,29,2,22,3.921720E+003,1,,,,,,
2014-09-15 14:44:00,3,,,,,,5,2,,,,
2014-09-15 14:44:00,3,,,,,,778,1,,,,
2014-09-15 14:44:00,3,,,,,,21,1,,,,
2014-09-15 14:44:00,3,,,,,,779,1,,,,
2014-09-15 14:44:00,0,,,,,,778,1,,,,
2014-09-15 14:44:00,0,,,,,,21,1,,,,
2014-09-15 14:44:00,3,,,,,,,,779,2,,
2014-09-15 14:44:00,3,,,,,,,,6,1,,
2014-09-15 14:44:00,0,,,,,,,,518,1,,
2014-09-15 14:44:00,0,,,,,,,,779,4,,
2014-09-15 14:44:00,3,,,,,,,,,,0,36
2014-09-15 14:44:00,3,,,,,,,,,,21,1
2014-09-15 14:44:00,0,,,,,,,,,,0,21
2014-09-15 14:44:00,0,,,,,,,,,,2835,1
```

Corresponding OMeS File

```
<OMeS>
    <PMSetup startTime="2014-09-21T10:00:00.000+00:00:00" interval="1">
            <PMMOResult>
                    <MO>
                            <DN>PLMN-PLMN/MSC-MSC01</DN>
                    </MO>
                    <PMTarget measurementType="Calls">
                            <call_setup_count>45</call_setup_count>
                            <call_setup_failure_count>5</call_setup_failure_count>
                            <call_duration_sum>87</call_duration_sum>
                            <call_answered_count>37</call_answered_count>
                            <call_dropped_count>1</call_dropped_count>
                    </PMTarget>
            </PMMOResult>
            <PMMOResult>
                    <MO>
                            <DN>PLMN-PLMN/MSC-MSC01/CC-05</DN>
                    </MO>
                    <PMTarget measurementType="CC">
                            <cc_signalling>2</cc_signalling>
                            <cc_ringing>0</cc_ringing>
                            <cc_speech>0</cc_speech>
                    </PMTarget>
            </PMMOResult>

            <PMMOResult>
                    <MO>
                            <DN>PLMN-PLMN/MSC-MSC01/CC-778</DN>
                    </MO>
                    <PMTarget measurementType="CC">
                            <cc_signalling>1</cc_signalling>
                            <cc_ringing>0</cc_ringing>
                            <cc_speech>0</cc_speech>
                    </PMTarget>
            </PMMOResult>

            <PMMOResult>
                    <MO>
                            <DN>PLMN-PLMN/MSC-MSC01/CC-21</DN>
                    </MO>
                    <PMTarget measurementType="CC">
                            <cc_signalling>1</cc_signalling>
                            <cc_ringing>0</cc_ringing>
                            <cc_speech>1</cc_speech>
                    </PMTarget>
            </PMMOResult>

            <PMMOResult>
                    <MO>
                            <DN>PLMN-PLMN/MSC-MSC01/CC-779</DN>
```

Figure 69: CSV and OMeS files comparison

This OMeS file would be the result of the mediation and adaptation processes.

The information contained in OMeS file is then stored in the database and becomes available to NPM.

Besides OMeS file, there are other mandatory files to perform this operation. One of them is the previously referred Koala Model. It defines the basic overall structure that should be used by the other files.

The next figure is a sample of this model for this specific case.


```xml
<com.nokia.oss.oss51:Metadata xmlns:com.nokia.oss.oss51="http://www.nokia.com/oss/oss51">
        <Adaptation ID="custrf" RepProcessID="0xFF17">


                <Release>
                        <Vendor>NSN</Vendor>
                        <Element>MSC</Element>
                        <Version>1.0</Version>
                </Release>

                <!-- PLMN/MSC/CC -->
                <Topology ID="ROOT" Path="PLMN-PLMN" Dimension="3G Network">
                        <Level ID="MSC" ObjectNumber="1" Aggregation="true" IsTransient="false" RBName="MSC">
                                <ObjectClassDefinition IntClassID="107" IsNE="true" Name="MSC_OBJECT_CLASS" />
                                <Key ID="msc_id" />
                  <Level ID="CC" ObjectNumber="40" Aggregation="true" IsTransient="true">
                  <ObjectClassDefinition IntClassID="0" IsNE="false"
                     Name="CC_OBJECT_CLASS"/>
                  <Key ID="cc_id" MaxLength="255"/>
                  </Level>
                        </Level>
                </Topology>

                <Measurement ID="CALLS" Aggregation="All" RBFolderName="Calls" OMeSName="Calls" NEName="Calls">
                        <Description>
                                   <![CDATA[Calls]]>
                        </Description>
                        <Time>
                                <RawLevel>15</RawLevel>
                                <FirstLevel>hour</FirstLevel>
                                <LastLevel>week</LastLevel>
                        </Time>
                        <TopologyRef ID="ROOT" SkipAggregation="false">
                                <RawLevelRef>ROOT.MSC</RawLevelRef>
                                <FirstLevelRef>ROOT.MSC</FirstLevelRef>
                                <LastLevelRef>ROOT</LastLevelRef>
                        </TopologyRef>
                        <PhysicalCounters>
                                <Counter ID="call_setup_count" OMeSName="call_setup_count" NEName="call_setup_count"
                                        FirstNERelease="1.0" Unit="Integer number" RBName="call_setup_count">
                                        <TimeRawFormula>SUM(call_setup_count)</TimeRawFormula>
                                        <Description><![CDATA[ call_setup_count]]></Description>
                                </Counter>
                                <Counter ID="call_setup_failure_count" OMeSName="call_setup_failure_count" NEName="call_setup_failure_count"
                                        FirstNERelease="1.0" Unit="Integer number" RBName="call_setup_failure_count">
                                        <TimeRawFormula>SUM(call_setup_failure_count)</TimeRawFormula>
                                        <Description><![CDATA[call_setup_failure_count]]></Description>
                                </Counter>
                                <Counter ID="call_duration_sum" OMeSName="call_duration_sum" NEName="call_duration_sum"
                                        FirstNERelease="1.0" Unit="Integer number" RBName="call_duration_sum">
                                        <TimeRawFormula>SUM(call_duration_sum)</TimeRawFormula>
                                        <Description><![CDATA[ call_duration_sum]]></Description>
                                </Counter>
                                <Counter ID="call_answered_count" OMeSName="call_answered_count" NEName="call_answered_count"
                                        FirstNERelease="1.0" Unit="Integer number" RBName="call_answered_count">
                                        <TimeRawFormula>SUM(call_answered_count)</TimeRawFormula>
                                        <Description><![CDATA[ call_answered_count]]></Description>
                                </Counter>
                                <Counter ID="call_dropped_count" OMeSName="call_dropped_count" NEName="call_dropped_count"
                                        FirstNERelease="1.0" Unit="Integer number" RBName="call_dropped_count">
                                        <TimeRawFormula>SUM(call_dropped_count)</TimeRawFormula>
                                        <Description><![CDATA[ call_dropped_count]]></Description>
                                </Counter>
                        </PhysicalCounters>
                </Measurement>
```


Figure 70: Koala model example

Other important files are those where content information related to counters and reports (description, counters presenting order, etc.) is defined.

In this case, I will refer to those files as Calls.xml (overview counters) and CC.xml (clear codes counters). Those files work at pairs, i.e. there are two files for Calls and two files for CC.

One file defines and describes the counters, as it is possible to observe in the next figure:

```
<kpi name="call_answered_count">
  <formula>CALLS.call_answered_count</formula>
  <kpi_info>
    <title>call_answered_count</title>
    <use>call_answered_count</use>
    <open_questions />
    <use_experience />
    <known_problems />                                    call_answered_count counter definition
    <pm_class />
    <formula>SUM(call_answered_count)</formula>
    <unit>#</unit>
    <tables>custrf_ps_calls_{OBJ_AGG}_{TIME_AGG}</tables>
  </kpi_info>
  <kpi_alias>call_answered_count</kpi_alias>
  <kpi_format>float:0</kpi_format>
  <kpi_mark />
  <area_level />
</kpi>
<kpi name="call_dropped_count">
  <formula>CALLS.call_dropped_count</formula>
  <kpi_info>
    <title>call_dropped_count</title>
    <use>call_dropped_count</use>
    <open_questions />
    <use_experience />                                      call_dropped_count counter definition
    <known_problems />
    <pm_class />
    <formula>SUM(call_dropped_count)</formula>
    <unit>#</unit>
    <tables>custrf_ps_calls_{OBJ_AGG}_{TIME_AGG}</tables>
  </kpi_info>
  <kpi_alias>call_dropped_count</kpi_alias>
  <kpi_format>float:0</kpi_format>
  <kpi_mark />
  <area_level />
</kpi>
<kpi name="call_duration_sum">
  <formula>CALLS.call_duration_sum</formula>
  <kpi_info>
```

Figure 71: Counters Definition

The complementary file “chooses” the counters to be used in the report as well as the report structure.

An example of that file is presented next:

```
</info>

<column_order>
  <period_duration />
  <call_setup_failure_count />
<call_answered_count />
  <call_dropped_count />
  <call_duration_sum />
  <call_setup_count />
</column_order>

<kpi_ref ref="custrf/counters/CALLS.xml#period_duration" />
<kpi_ref ref="custrf/counters/CALLS.xml#call_setup_failure_count" />
<kpi_ref ref="custrf/counters/CALLS.xml#call_answered_count" />
<kpi_ref ref="custrf/counters/CALLS.xml#call_dropped_count" />
<kpi_ref ref="custrf/counters/CALLS.xml#call_duration_sum" />
<kpi_ref ref="custrf/counters/CALLS.xml#call_setup_count" />

</conf_file>
```

Column order in the report

Chosen counters to appear in this report

Figure 72: Chosen counters

Besides the indication of the chosen counters, this file also indicates the path to those same counters. In this case, the path is ‘custrf/counters/’ and the file name is CALLS.xml. The file indicated here corresponds to the file presented in figure 71.

Note that this presented example is related to Calls (network overview) but it works the same way for Clear Codes counters.

All of these files have their importance and they are all interconnected. One way to illustrate that connection is to consider that they lay on top of each other.

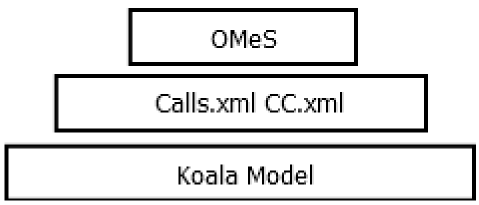


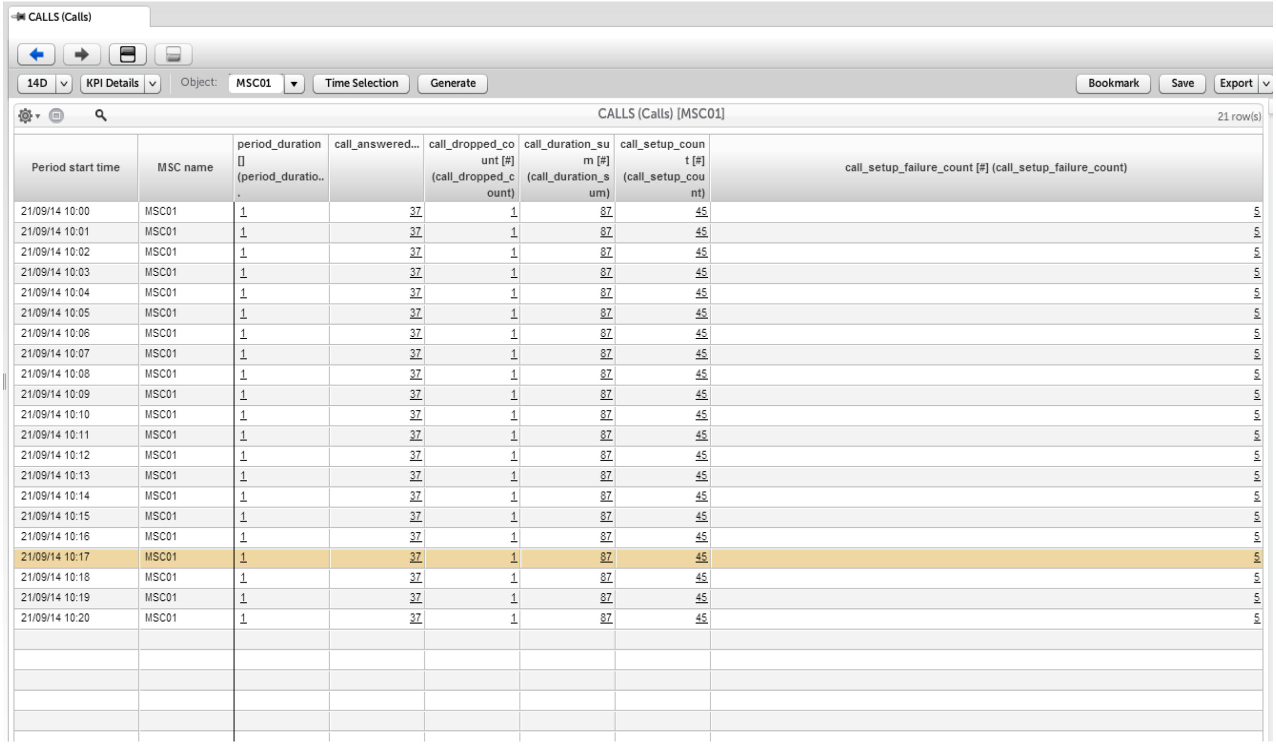
Figure 73: PoC files interconnection

The Koala model represents the foundation because it sets the model for the entire integration, including initialization and basic definition of measures, counters and KPIs.

On top of that, there are the files responsible for the organization of the information (Calls.xml and CC.xml).

Finally, on top of them, there is the OMeS file which carries the data itself. This must be in conformity with the other files, otherwise some data may not be perceived.

As it is at this moment, there are only counters in OMeS file, and if we use them directly, the report should look like the one that is presented next:



Period start time	MSC name	period_duration [] (period_duratio...	call_answered...	call_dropped_count [#] (call_dropped_count)	call_duration_sum [#] (call_duration_sum)	call_setup_count [#] (call_setup_count)	call_setup_failure_count [#] (call_setup_failure_count)
21/09/14 10:00	MSC01	1	37	1	87	45	5
21/09/14 10:01	MSC01	1	37	1	87	45	5
21/09/14 10:02	MSC01	1	37	1	87	45	5
21/09/14 10:03	MSC01	1	37	1	87	45	5
21/09/14 10:04	MSC01	1	37	1	87	45	5
21/09/14 10:05	MSC01	1	37	1	87	45	5
21/09/14 10:06	MSC01	1	37	1	87	45	5
21/09/14 10:07	MSC01	1	37	1	87	45	5
21/09/14 10:08	MSC01	1	37	1	87	45	5
21/09/14 10:09	MSC01	1	37	1	87	45	5
21/09/14 10:10	MSC01	1	37	1	87	45	5
21/09/14 10:11	MSC01	1	37	1	87	45	5
21/09/14 10:12	MSC01	1	37	1	87	45	5
21/09/14 10:13	MSC01	1	37	1	87	45	5
21/09/14 10:14	MSC01	1	37	1	87	45	5
21/09/14 10:15	MSC01	1	37	1	87	45	5
21/09/14 10:16	MSC01	1	37	1	87	45	5
21/09/14 10:17	MSC01	1	37	1	87	45	5
21/09/14 10:18	MSC01	1	37	1	87	45	5
21/09/14 10:19	MSC01	1	37	1	87	45	5
21/09/14 10:20	MSC01	1	37	1	87	45	5

Figure 74: NPM report with Traffica counters

In this report, only Traffica counters are presented. As the main goal is to present the chosen KPIs, it is necessary to perform some calculations over those counters.

7.3.3 KPIs Definition

In this sub section, the most important details related to the wanted KPIs definition are presented.

<u>CSSR</u>

```
<conf_file>
  <temp_table_ref src="custrf/counters/CALLS.xml"/>
  <kpi name="CSSR">
    <formula>((CALLS.call_setup_count-CALLS.call_setup_failure_count)/(CALLS.call_setup_count))*100</formula>
```

It is possible to observe the formula and the path to the used counters – “custrf/counters/CALLS.xml”. In this case, the counters that were used to calculate this KPI were ‘call_setup_count’ and ‘call_setup_failure_count’.

Following the same method for the other KPIs:

Total Conversation Time

```
<conf_file>
  <temp_table_ref src="custrf/counters/CALLS.xml"/>
  <kpi name="TotConvTime">
    <formula>(CALLS.call_duration_sum)/60</formula>
```

Average Call Duration

```
<conf_file>
  <temp_table_ref src="custrf/counters/CALLS.xml"/>
  <kpi name="AvgCallDuration">
    <formula>((CALLS.call_duration_sum)/60)/(CALLS.call_answered_count)</formula>
```

Drop Call Ratio

```
<conf_file>
  <temp_table_ref src="custrf/counters/CALLS.xml"/>
  <kpi name="DCR">
    <formula>100*(CALLS.call dropped count) /(CALLS.call answered count)</formula>
```

The 'Failed Calls' KPI represents the calls that ended in some of the predefined 'Failure Clear Codes'. These Clear Codes were chosen in the OMeS files, and in a real implementation the user can configure the clear codes to be considered.

In this case, the considered clear codes are the following:

```
cc_id IN (4, 5, 6, 7, 518, 778, 779, 2835) THEN
EN cc_id IN (4, 5, 6, 7, 518, 778, 779, 2835) T
c_id IN (4, 5, 6, 7, 518, 778, 779, 2835) THEN
```

Figure 75: 'Failure Clear Codes'

And the number of failed calls is:

```
<kpi name="FailCalls">
  <formula>CC.cc ringing 1 + CC.cc signalling 1 + CC.cc speech 1</formula>
```

, which is the sum of 'Failure Clear Codes' occurrences in each call phase.

Successful Calls

```
<conf_file>
  <temp_table_ref src="custrf/counters/CALLS.xml"/>
    <temp_table_ref src="custrf/counters/CC.xml"/>
  <kpi name="SuccCalls">
    <formula>(CALLS.call setup count) - (CC.cc ringing 1 + CC.cc signalling 1 + CC.cc speech 1)</formula>
```

7.3.4 Data Simulation

It is possible to use the PM Data Simulator tool to simulate real time data coming from Traffica. In this case, we have four different OMeS files with simulated data and, in each minute, the tool randomly chooses one of those files and puts it into the database. Then, that file is processed based on what it was presented. After a minute, another file is randomly chosen and loaded into the database.

The whole process is illustrated in the next figure:

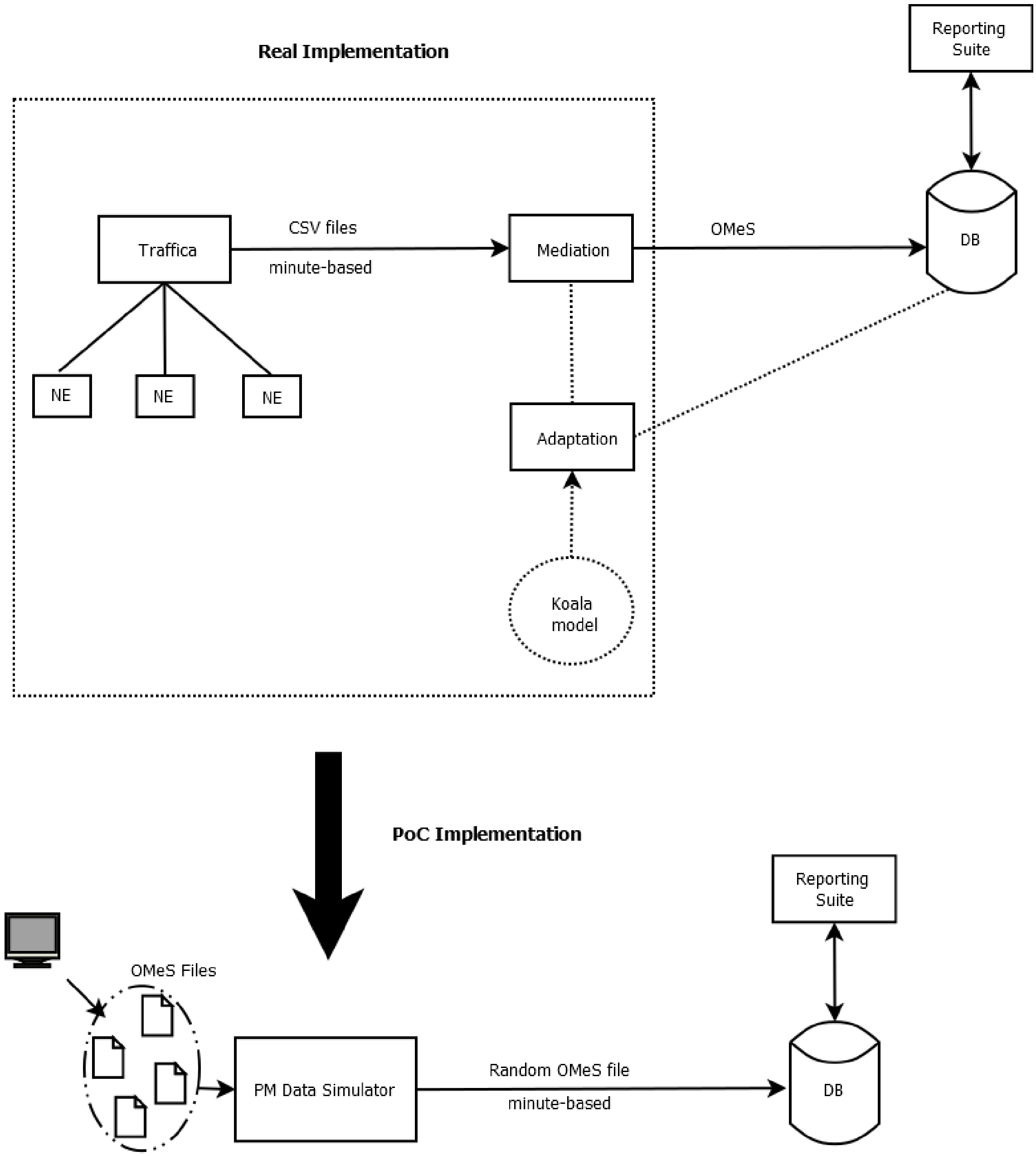


Figure 76: Real and Simulated implementation (drawn by the author)

With this method, there will be only 4 possible different results, but is enough to prove that this PoC is working fine and would be ready to receive real data.

7.3.5 Followed Procedure (Step by Step)

It is presented a step by step summary of what was done in terms of files creation and configuration. All of those steps were made in a Nokia Lab specifically designed for testing functionalities.

1. Configure Koala Model
2. Create OMeS file with the wanted counters to simulate data from Traffica
3. Create XML file with those counters definition
4. Create XML files with KPIs definition (based on previous counters). It is needed one file per each wanted KPI
5. Create XML file to define the Report content such as counters and KPIs to be presented and their appearance order
6. Configure that same file in order to add some functionalities. At this stage, chart presentation configuration and drill capabilities were added.
7. Create more OMeS files(same structure but different values) and add them to PM Data Simulator
8. Configure the Simulator to randomly choose one OMeS file every minute and put it into the database
9. Run NPM

7.3.6 Results

With this configuration, the Reporting Suite page assumes the following “look”:

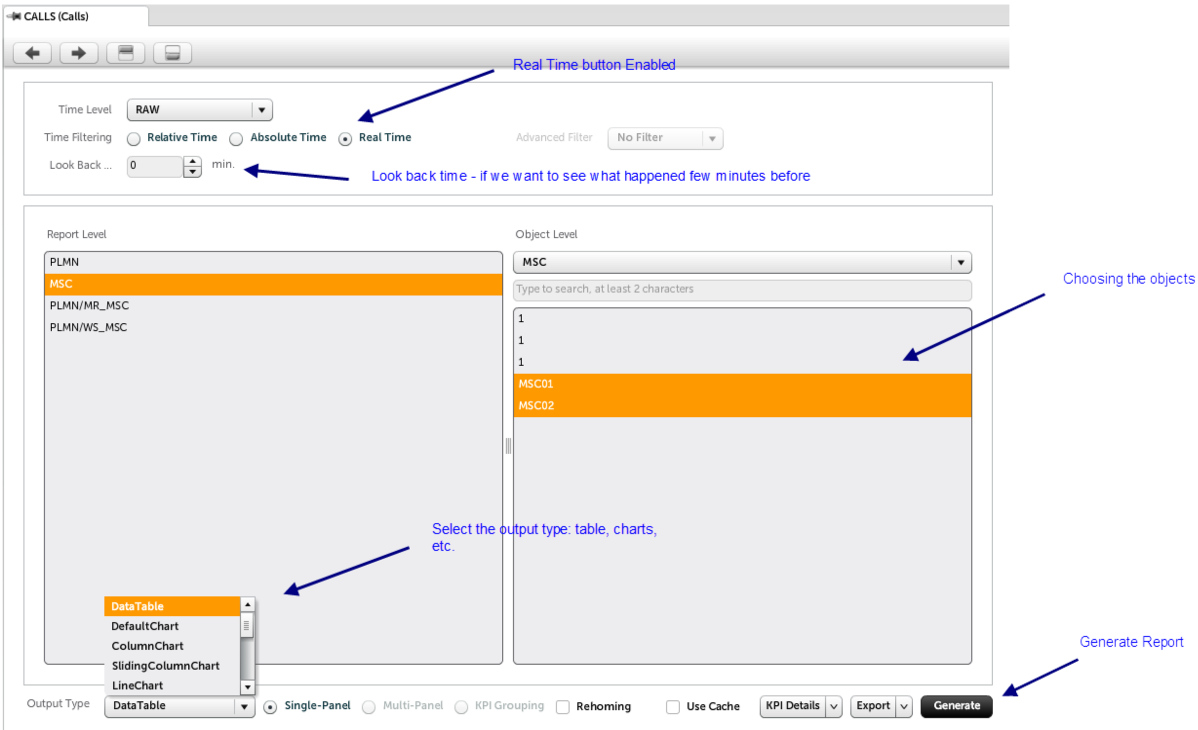


Figure 77: Reporting Suite page

The blue arrows highlight the most important items.

The report that arises from the ‘Generate Report’ button is presented next. Note that this report is updated automatically every minute.

CALLS (Calls) [MSC01+] 3 row(s)

Period start time 1▼	MSC name	Period Duration [min] (period_duratio.. .	Setup Phase: Call Setup Success Ratio [%] (CSSR)	Setup Phase: Call Setups [#] (call_setup_count)	Setup Phase: Call Setup Failures [#] (call_setup_failure_count)	Answered: Answered Calls [#] (call_answered_count)	Conversation - Time: Total Conversation Time [min] (TotConvTime)	Conversation - Time: Average Call Duration [min] (AvgCallDuration)	Conversation - Time: Total Call Duration [Seconds] (call_duration_sum)	Conversation - Dropped Calls: Drop Call Ratio [%] (DCR)	Conversation - Dropped Calls: Total Dropped Calls [#] (call_dropped_count)
21/10/14 09:03	MSC01	1	91,25	3.715	325	3.120	31	0,01	1.860	3,37	105
21/10/14 09:02	MSC01	1	91,25	3.715	325	3.120	31	0,01	1.860	3,37	105
21/10/14 09:01	MSC01	1	91,25	7.430	650	6.240	62	0,01	3.720	3,37	210

Figure 78: Final Report - Part 1

CALLS (Calls) [MSC01+] 6 row(s)

Period start time 1▼	MSC name	Calls Analysis: Total Nbr Calls [#] (TotalCalls)	Calls Analysis: Failed Calls [#] (FailCalls)	Calls Analysis: Successful Calls [#] (SuccCalls)
21/10/14 09:06	MSC01	7.430	1.440	5.990
21/10/14 09:05	MSC01	7.430	1.440	5.990
21/10/14 09:04	MSC01	11.145	2.160	8.985
21/10/14 09:03	MSC01	3.715	710	3.005
21/10/14 09:02	MSC01	3.715	710	3.005
21/10/14 09:01	MSC01	7.430	1.440	5.990

Figure 79: Final Report - Part 2

In this report, we have the most important Traffica counters along with the wanted KPIs.

Besides data table, it is also possible to present the same information in other different formats.

This is an important possibility because sometimes it is easier to “read” the information in a graphical way than in tables.

So, NPM offers the possibility to analyze KPI grouping graphically, by choosing Default Chart as Output type:

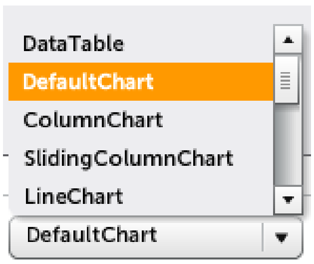


Figure 80: Default Chart

It is possible to observe the graphs in the next figures.

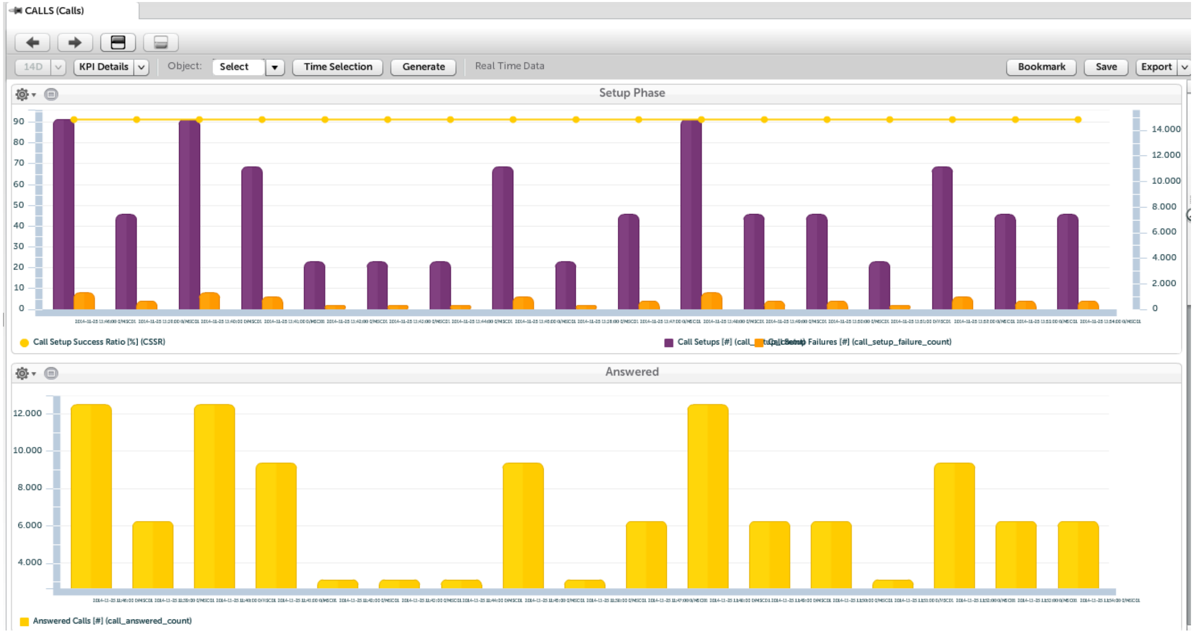


Figure 81: Setup Phase and Answered KPIs as default chart

To analyze these charts it is important to refer that the KPIs on the left must be read in the left scale and the ones that are on the right must be read on the right scale.

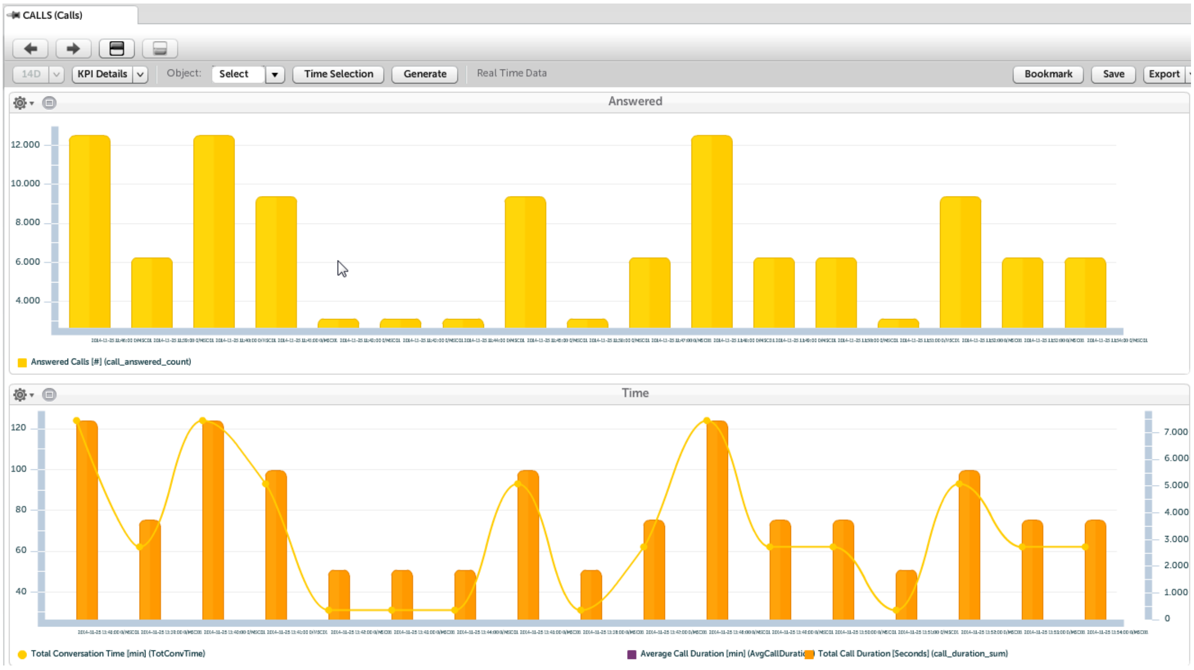
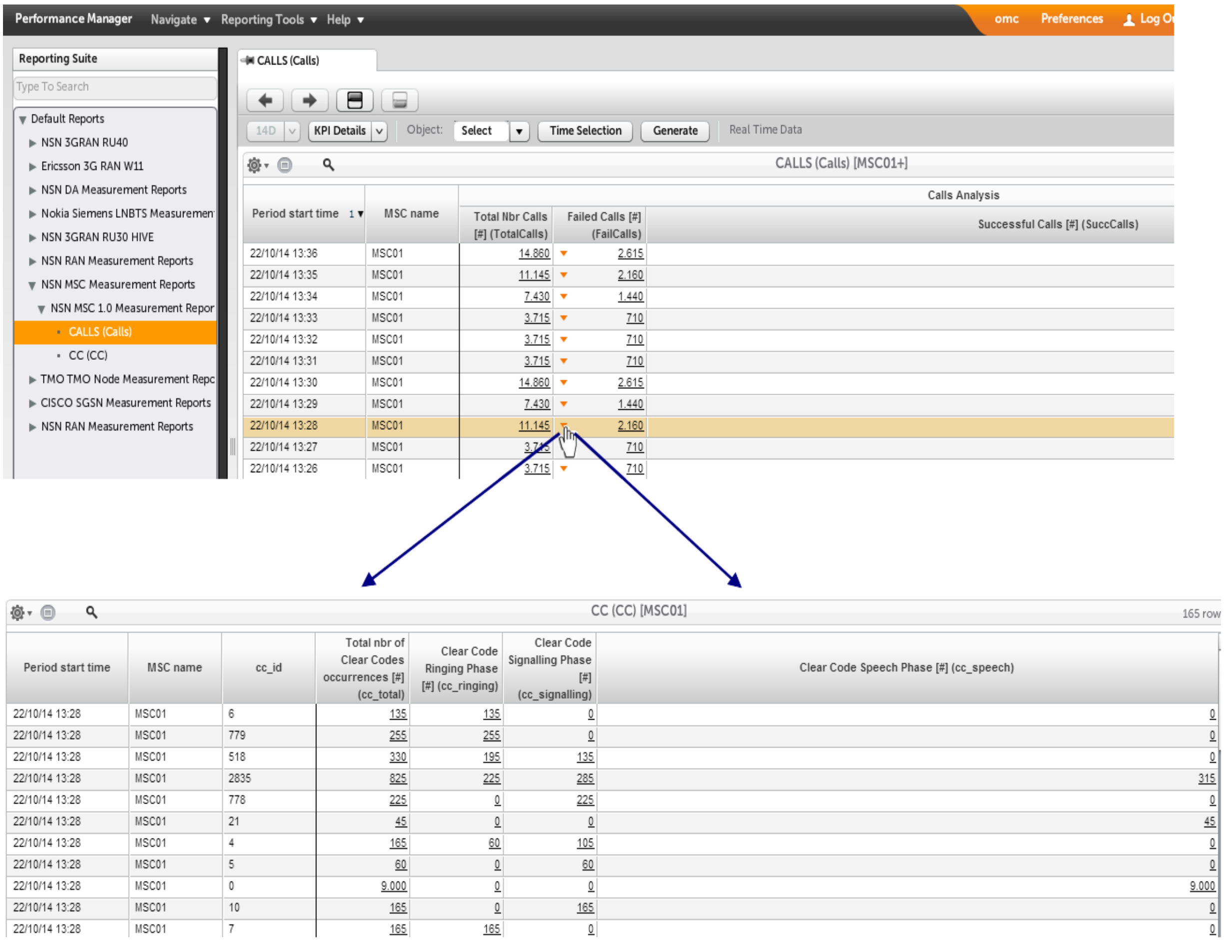


Figure 82: Answered and Time related KPIs as default chart

This type of view presents the KPIs organized by groups. This means that is possible to analyze all the KPIs that are related to Setup Phase, Dropped Calls, etc. in one window.

Figure 83: Dropped Calls and Calls Analysis KPIs as default chart

Besides these features, this report also has drill capabilities, which are particularly interesting in the ‘Failed Calls’ KPI.



Period start time	MSC name	Total Nbr Calls [#] (TotalCalls)	Failed Calls [#] (FailCalls)	Successful Calls [#] (SuccCalls)
22/10/14 13:36	MSC01	14.860	2.615	
22/10/14 13:35	MSC01	11.145	2.160	
22/10/14 13:34	MSC01	7.430	1.440	
22/10/14 13:33	MSC01	3.715	710	
22/10/14 13:32	MSC01	3.715	710	
22/10/14 13:31	MSC01	3.715	710	
22/10/14 13:30	MSC01	14.860	2.615	
22/10/14 13:29	MSC01	7.430	1.440	
22/10/14 13:28	MSC01	11.145	2.160	
22/10/14 13:27	MSC01	3.7[illegible]5	710	
22/10/14 13:26	MSC01	3.715	710	

Period start time	MSC name	cc_id	Total nbr of Clear Codes occurrences [#] (cc_total)	Clear Code Ringing Phase [#] (cc_ringing)	Clear Code Signalling Phase [#] (cc_signalling)	Clear Code Speech Phase [#] (cc_speech)
22/10/14 13:28	MSC01	6	135	135	0	0
22/10/14 13:28	MSC01	779	255	255	0	0
22/10/14 13:28	MSC01	518	330	195	135	0
22/10/14 13:28	MSC01	2835	825	225	285	315
22/10/14 13:28	MSC01	778	225	0	225	0
22/10/14 13:28	MSC01	21	45	0	0	45
22/10/14 13:28	MSC01	4	165	60	105	0
22/10/14 13:28	MSC01	5	60	0	60	0
22/10/14 13:28	MSC01	0	9.000	0	0	9.000
22/10/14 13:28	MSC01	10	165	0	165	0
22/10/14 13:28	MSC01	7	165	165	0	0

Figure 84: Report Drill Capabilities

This is very important because allows to know clear codes occurrences in real time and the call phase of that occurrence, which are the main parameters needed to define the failure reason. In this example, it is possible to see the Clear Code Id and the number of occurrences per phase (Signaling, Ringing and Speech).

It is possible to observe that Clear Code 2835, for an example, occurred 825 times. It occurred 225 times in Ringing Phase, 285 times in Signaling Phase and 315 times in Speech Phase. If we consult Appendix A, we notice that it corresponds to a Clear Code that indicates ‘Radio Interface Failure’, which means that the Radio Network may be experiencing some problems.

Note that for this analysis, a conversion from Decimal to Hexadecimal is needed. In this particular case, 2835 ↔ 0B13H.

8. Concluding Remarks

8.1 Conclusions

This dissertation aimed to explain the need for Performance Management Systems and why those systems need to be perfected. At the same time, a possible improvement is presented and within this context, it is possible to state that the main goal of this dissertation was to present a proof of concept to show that Traffica and NPM integration is possible and would bring many advantages to the Telecommunications Mobile Networks Operators.

In that context, it was important to answer some questions that might have arisen. Why is this issue important? How do those tools work? How can we implement this integration? What kind of data is worth to include in it?

The study of Telecommunications networks evolution and operation mode helped in answering to the first question. There are different technologies, several provided services and procedures, which turn these into very complex networks. That is why it is important to improve Performance Management Systems.

Then, the study of Nokia tools is mandatory in order to understand how they work and how this integration may be implemented.

To answer the final question, a study of Traffica counters is needed. We need to know what kind of counters can be provided by Traffica for “building” useful KPIs.

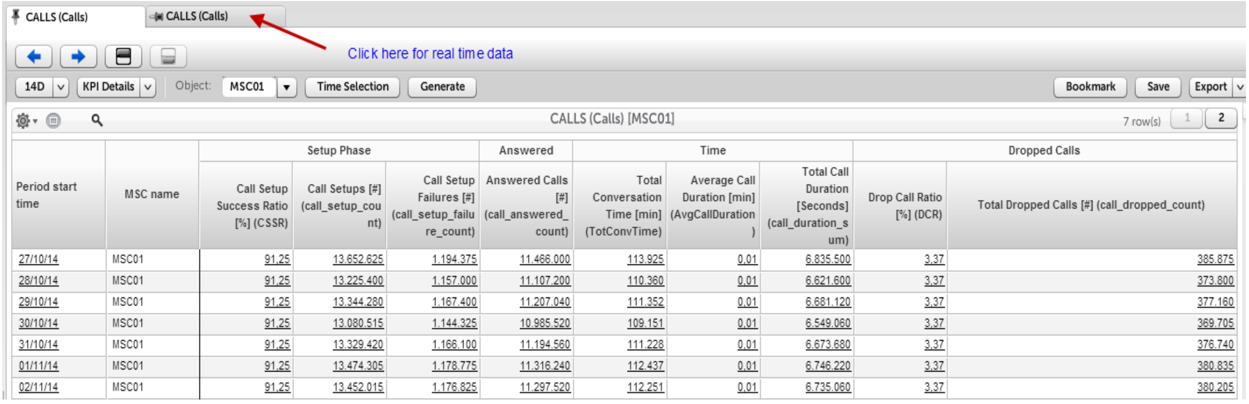
The choice of the KPIs to be implemented is really important because this is a real time application and it is not possible to transfer a big quantity of data. Because of that, only the more meaningful information should be considered.

I think those questions were answered and clarified, and after that, we were in conditions to develop the Proof of Concept.

Although this Proof of Concept uses simulated data, it is possible to state that it is able to underline the idea that it may be useful to network operators. It presents meaningful real time data in different interesting ways and allows drill capabilities to quickly spot any problem that may happen. The combination of those elements results in a versatile and powerful tool.

However, there are some aspects in this PoC that aren´t working 100% or it wasn´t possible to test them. It is not possible to present an interesting feature that is drilling from long term to real time data capability. As it is simulated data, testing and implementation of that feature wasn´t possible nor was it considered. In this case, we chose the real time data to be put in the database but it is not possible to do the same thing with historical data.

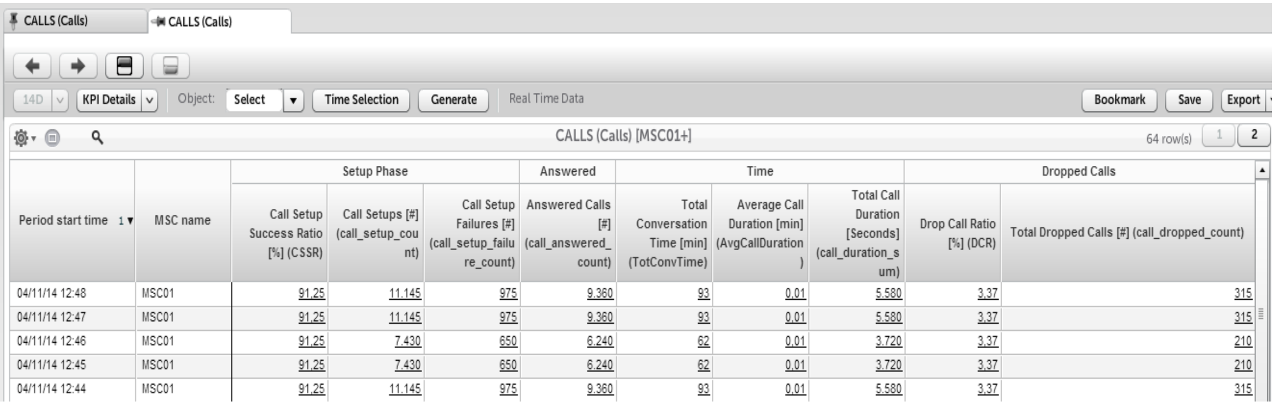
Although this drill functionality is not implemented, it is possible to analyze historical data and real time data at (almost) the same time by having two reports running simultaneously.



Period start time	MSC name	Setup Phase			Answered	Time			Dropped Calls	
		Call Setup Success Ratio [%] (CSSR)	Call Setups [#] (call_setup_count)	Call Setup Failures [#] (call_setup_failure_count)	Answered Calls [#] (call_answered_count)	Total Conversation Time [min] (TotConvTime)	Average Call Duration [min] (AvgCallDuration)	Total Call Duration [Seconds] (call_duration_sum)	Drop Call Ratio [%] (DCR)	Total Dropped Calls [#] (call_dropped_count)
27/10/14	MSC01	91,25	13.652.625	1.194.375	11.466.000	113.925	0,01	6.835.500	3,37	385.875
28/10/14	MSC01	91,25	13.225.400	1.157.000	11.107.200	110.360	0,01	6.621.600	3,37	373.800
29/10/14	MSC01	91,25	13.344.280	1.167.400	11.207.040	111.352	0,01	6.681.120	3,37	377.160
30/10/14	MSC01	91,25	13.080.515	1.144.325	10.985.520	109.151	0,01	6.549.060	3,37	369.705
31/10/14	MSC01	91,25	13.329.420	1.166.100	11.194.560	111.228	0,01	6.673.680	3,37	376.740
01/11/14	MSC01	91,25	13.474.305	1.178.775	11.316.240	112.437	0,01	6.746.220	3,37	380.835
02/11/14	MSC01	91,25	13.452.015	1.176.825	11.297.520	112.251	0,01	6.735.060	3,37	380.205

Figure 85: Report with daily information

In this report we have last week information, and clicking on the other tab, it is possible to see real time data for the same MSC or, in other words, see what is happening "now".



Period start time 1 ▾	MSC name	Setup Phase			Answered	Time			Dropped Calls	
		Call Setup Success Ratio [%] (CSSR)	Call Setups [#] (call_setup_count)	Call Setup Failures [#] (call_setup_failure_count)	Answered Calls [#] (call_answered_count)	Total Conversation Time [min] (TotConvTime)	Average Call Duration [min] (AvgCallDuration)	Total Call Duration [Seconds] (call_duration_sum)	Drop Call Ratio [%] (DCR)	Total Dropped Calls [#] (call_dropped_count)
04/11/14 12:48	MSC01	91,25	11.145	975	9.360	93	0,01	5.580	3,37	315
04/11/14 12:47	MSC01	91,25	11.145	975	9.360	93	0,01	5.580	3,37	315
04/11/14 12:46	MSC01	91,25	7.430	650	6.240	62	0,01	3.720	3,37	210
04/11/14 12:45	MSC01	91,25	7.430	650	6.240	62	0,01	3.720	3,37	210
04/11/14 12:44	MSC01	91,25	11.145	975	9.360	93	0,01	5.580	3,37	315

Figure 86: Report with minute-based information

This is very important because the network analysis become much more effective. If there is any problem spotted in a certain day, it is possible to analyze in real time that same MSC. With that analysis is possible to know if there is a real problem or if it was just an isolated event.

Comparing with NPM alone, it is possible to conclude that this PoC complements all the other NPM functionalities with the most important real time data and encompasses in fact, the best of NPM and Traffica. Because of that, it may constitute a quality differentiating tool for Nokia, and has the potential to be successful in this market.

Besides the PoC itself, I think CSV files analysis (7.2.1) added extra value to this particular work and the proof is that conversations have been initiated in order to modify CSV files structure.

At this point, it is known neither what changes are going to be made nor if those changes will be implemented. Anyway, the existence of such conversations can be considered a positive indication in relation to the developed work.

8.2 Future Work

There are some interesting features that may be worth to study in more detail in future work. The integration of SGSN and MGW real time KPIs as well as mobile type KPIs is one of them. The integration of these KPIs would extend the view over the network and may help to identify some other problems that are imperceptible to MSS. Having those referred real time KPIs along with long term KPIs would represent a big advantage to the operators because they would have a complete overview of the network.

As it was referred in previous sub-section, other issue that may be studied in more detail is the CSV files structure. The information to transfer is supposed to be real time information and therefore, the transmission and the processing of the information should be as fast as possible. With the tests that have been made, it seems that the structure in use is not the most appropriate and there are more profitable options. So, a deep study of this issue may be important, not only to this particular case, but to other situations since CSV files are used in a relatively frequent way.

Another aspect that may be improved is the integration of Hadoop and Storm. As they introduce more efficient and robust data partitioning processes, they may be important in future applications especially when dealing to a large quantity of data.

The drilling from historical data to real time data is another aspect that may be studied and tested in future work. Although it is possible to have the two types of data in two “parallel” windows, it is not much convenient.

Having the drill functionality would be much more intuitive and user friendly and that is why it should be considered in future work as a mandatory upgrade. It could be a “simple” drilling or it might be something like Traffica CQIM mode of operation that is presented next:

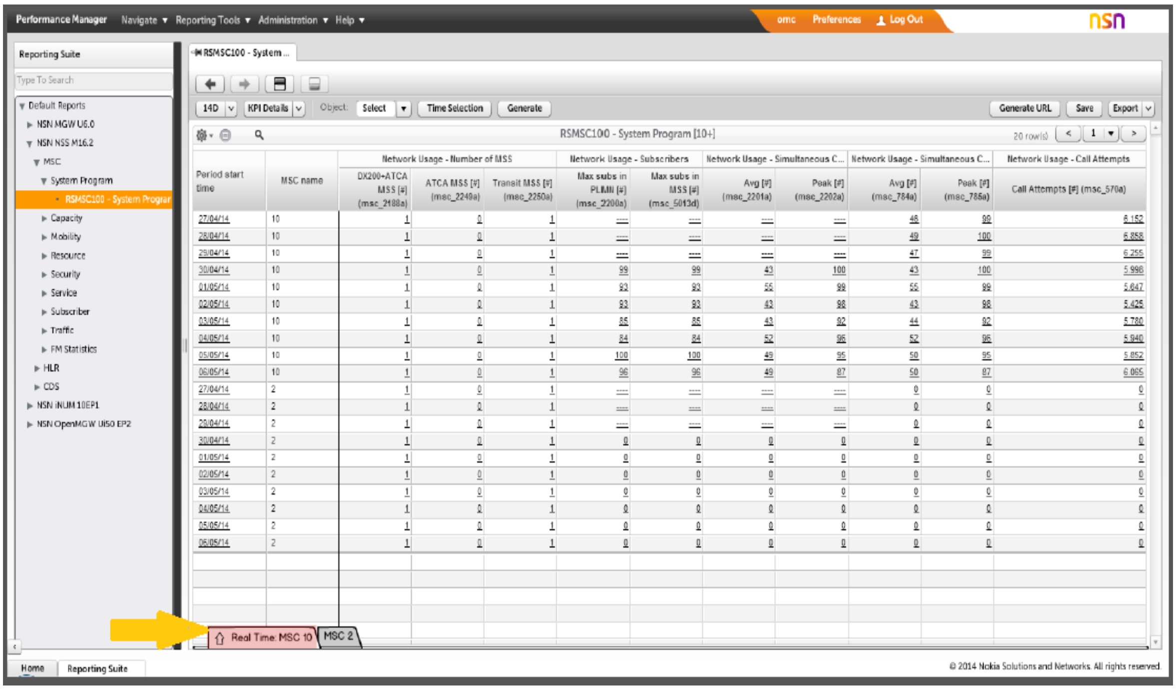


Figure 87: Traffica CQIM approach - Part 1

And by clicking in Real time Tab (yellow arrow), real time graphs would show up:

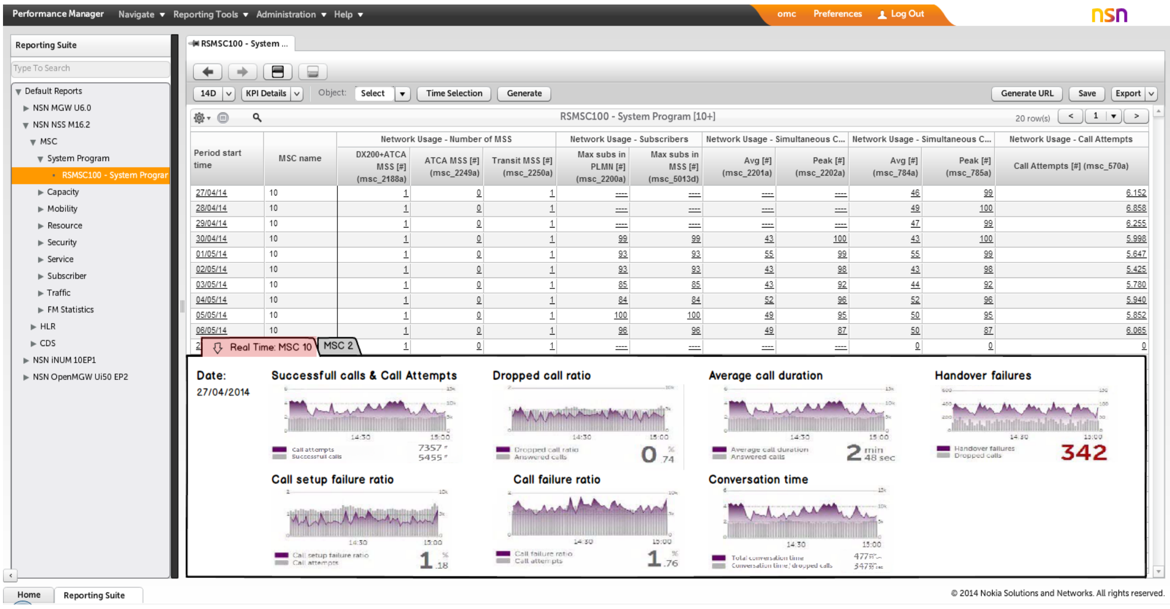


Figure 88: Traffica CQIM approach - Part 2

In this case, it would be possible to analyze the two kinds of data at the same time.

The presented data is not related with this dissertation. What really matters is that this is a much more user friendly representation and could be an alternative to the simple drilling.

If the operators spot a period with a lot of failure calls, for an example, with that information alone is not possible to know if there is a problem or is just an abnormal punctual situation (concerts, etc.). If they could drill to real time data, they would know very quickly what is happening and would be able to understand the problem with the help of real time clear codes.

This is just an example of the importance of this feature and why it should be studied in more detail.

The incorporation of Clear Codes description in the reports may also be useful for a quicker understanding of the situation.

Although this wasn´t implemented in this report, it would be possible to have the following:

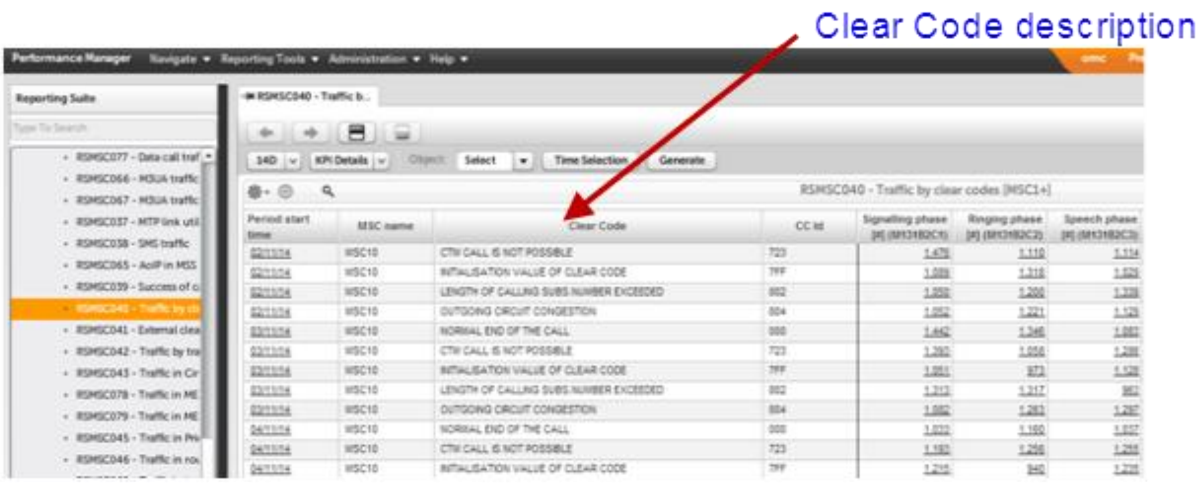


Figure 89: Clear Code description

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Appendix A – Clear Codes

MSS Clear codes (based on [13])

Normal Clearing:

Number	Name/Description
0000	Incoming or Outgoing Call that ended successfully
0004	Called Subscriber busy, or congestion has been received from the outgoing call
0005	The called subscriber is busy, or the clear code prevents Call Forwarding on Mobile Subscriber if the number of call forwardings has been exceeded. This clear code is also used if the called subscriber rejects a call in the ring phase
0006	The called subscriber has not answered within the time supervision. This clear code also prevents Call Forwarding on No Reply if the number of call forwardings has been exceeded
0007	A subscriber who has the call waiting facility has not answered a waiting call within the time supervision
000B	The called subscriber has a facility which directs the call to a manual answering service by means of rerouting
000C	The operating state 'crisis' of the exchange prevents call establishment
000D	Call has been cleared by the operator
0010	The operation concerns a subscriber who is unallocated, not registered, or in 'IMSI detach' state
0011	The call is cleared because of a priority call
0012	Mobile-terminating call cannot be connected because the MS is not found in paging
0013	The calling subscriber (A) who has call transfer with recall facility has transferred the call to a third party (subscriber C), but the answering time of subscriber C has expired. The transferred call is cleared and the original call between subscriber A and B is re-established
0015	Normal unspecified clearing
0016	Subscriber's charging capacity has been exceeded in the exchange
0017	Accumulated call meter exceeded
0019	HSS GW Service initiated call release
0021	Subscriber B is busy. It is possible to activate a CCBS call
0022	Subscriber B is busy. It is not possible to activate a CCBS call
0023	Maximum number of call transfers exceeded
0024	Call duration has exceeded the maximum value given by the operator
0025	Call has been released due to the Call Drop Back function
0026	Subscriber B is busy. It's possible to activate a CCBS call to a subscriber with a mobile station that supports CCBS
0027	Hunting Service Release
0028	Call has been deflected by subscriber B

0029	Used if the number of call forwardings has been exceeded in CFB, CFNR or CFU cases
002A	Roaming Retry
0030	Used if the number of call forwardings has been exceeded in CFNA case
0034	The call is rerouted from the GMSC in case of call forwarding. The connection is released from the VMSC to the GMSC
0036	The CLI is not available in the call and the called party has the anonymous call rejection feature activated. Call is cleared by the Service Attribute Analysis
0037	64 kbps multimedia or data call is not allowed from the incoming circuit group or towards the outgoing route
0038	Premium rate ping call is detected. It is not allowed
0040	Collect call is not accepted by the called party. Collect call restriction flag is set to the called party in HLR
0041	Is set when there is a premium rate SMS, which is not allowed for the subscriber, detected
0042	Is set by the short message handling functions in the case of a blocked SMS, based on content or blacklist filtering
0043	Triggers releasing of the new call leg and starts SR-VCC procedure
0044	Triggers releasing of the new call leg and starts dual radio VCC procedure
0045	The Location Update failed during SRVCC
0100	Circuit Re-seized
0101	Circuit Released before ‘end of the call’ notice
0102	Calibration of a call file releases a call which remains seized in the statistics
0104	ECT prevented due to CPH configuration
0105	MPTY prevented due to CPH configuration
0106	The Optimal Routing Interrogation Indicator is in the HLR enquiry special route data, but the feature is not active
0201	Outgoing signaling has responded to the seizure with an unknown message or an unknown line signal
0202	Clear request received from outgoing circuit
0203	The terminal equipment of an ISDN subscriber does not accept the B channel offered by the exchange
0204	A Call Set-up is attempted on a channel already occupied by another call
0205	The request radio channel is supported, but there are no radio channels available at that moment
0206	Call Rejected
0207	The terminal equipment of an ISDN subscriber has informed the exchange that the resources needed for call reception are not available
0208	The mobile subscriber has lost connection to the MSC and call re-establishment has failed
0210	The reason for release is either unknown or it has been received earlier
0211	The called subscriber does not accept diverted calls
0212	Called number is faulty
0213	Subscriber is not a member of the closed user group

0214	An unidentified call cannot be routed to the adjacent exchange
0216	Erroneous inclusion of a trunk prefix in the called party number
0220	The called subscriber does not accept anonymous calls
0221	Number is found to be “ported out” in SRRi
0250	MS is not subscriber of service centre
0251	Call is released because the calling and the called party are machines(voice mail case, for an example)
0252	Unterminated call to a ported number
0300	Subscriber A barred due to restriction in the outgoing direction
0301	Outgoing calls of calling subscriber barred by operator
0304	Incoming calls have been barred by the operator for some reason (subscriber out of service, outside his home area, etc.)
0306	Subscriber has prevented the call with the supplementary service of incoming call barring
0307	The called number is unused
0308	The number of the called subscriber has changed
030A	The connection has been cleared in the set-up phase either because the calling subscriber has made onhook or because a signal or message equivalent to clearing has been received from the incoming circuit
030B	The calling subscriber has made onhook before the called subscriber has answered, or a signal or message equivalent to clearing has been received from the incoming circuit
030C	Subscriber has not reanswered within the time limit
030E	The called subscriber is in line blocking state
0310	The call is rejected because the closed user group is unspecified
0311	Bearer service not provisioned
0312	Teleservice not provisioned
0313	Authentication of a mobile subscriber failed
0314	There is no data of the subscriber in the VLR
0315	Called subscriber has call diversion barring activated
0316	The memory capacity of the subscriber station has been exceeded
0317	Overall time limit of IN-based subscriber service has been reached
0318	The subscriber has switched off the terminal equipment during a call or call setup
0319	The subscriber station is illegal
031A	The call has been rejected because of an incoming call barring within the CUG
031C	The call has been rejected because the subscriber is not a member of the CUG
031D	The call has been rejected because of an outgoing call barring within the CUG
031E	The call is rejected, because the CUG index is incompatible with the requested basic service
031F	The call is rejected, because the requested basic service violates CUG restrictions

0320	The call is rejected, because the CUG restrictions of the called subscriber prevent the use of the supplementary service
0321	The call has been rejected, because no CUG had been selected
0322	The call has been rejected because of an unknown CUG index
0323	Trying to use multicall supplementary service has been rejected
0324	Multivendor Network resource optimization
0327	MSS initiated a recall request towards a subscriber but no confirmation or rejection has arrived
032D	Media or service is not supported

Table 8: Clear Codes - Normal Clearing [13]

Internal Congestion:

Number	**Name/Description**
0401	No free circuits available in the interworking unit
0402	Register total time exceeded
0403	MFCU device congestion
0404	PBRU device congestion
0405	Erroneous request from co-process
0406	Connection failed in GSW/SWI
0407	Erroneous answer from partner program block
0408	The length of the called subscriber's number has been exceeded
040A	Circuit congestion due to traffic type
040B	Hop counter exhausts in the exchange
040C	An attempt to start MAP service failed because of limited resources or congestion
040D	Roaming number has either not been reserved in the VLR, or it is unknown
040E	Roaming is not allowed
0410	GT analysis has failed
0417	Unit has been removed from H.248 traffic
0418	Result of SMS Attribute Analysis is BLOCK
0419	Unit removed from traffic
0420	No suitable cells in Location Area
0421	Incoming SIP request is rejected due to the fact that the incoming SLA rate limit of the request type defined for the source FQDN has been exceeded
0422	Outgoing SIP request is rejected due to the fact that the outgoing SLA rate limit of the request type defined for the destination FQDN has been exceeded
0423	Incoming SIP session establishment request is rejected due to the fact that the number of parallel sessions specific incoming SLA limit defined for the source FQDN has been exceeded

0424	Outgoing SIP session establishment request is rejected due to the fact that the number of parallel sessions specific outgoing SLA limit defined for the destination FQDN has been exceeded
0426	The incoming SIP request is rejected due to the fact that the combined SLA rate limit of the request type defined for the source FQDN has been exceeded
0427	The outgoing SIP request is rejected due to the fact that the combined SLA rate limit of the request type defined for the destination FQDN has been exceeded
0428	Incoming SIP session establishment request is rejected due to the fact that the number of parallel sessions specific combined SLA limit defined for the source FQDN has been exceeded
0429	Outgoing SIP session establishment request is rejected due to the fact that the number of parallel sessions specific combined SLA limit defined for the destination FQDN has been exceeded
0450	No User Plane Destination Reference (UPDR) ID has been defined for the incoming circuit group
0451	UPDR has not been defined for the outgoing route
0508	Error in establishing charging during the call
0509	Contents of a file are faulty, or an attempt to read the file has failed
0510	Is set if the MARKER unit, in which the routing information of the circuits were stored, is restarted
0511	Is used if a MGW-MGW interconnecting circuit has to be taken out of use due to a system-initiated state change, and therefore the call must be released
0512	Is used if a MGW-MGW interconnecting circuit has to be taken out of use due to a user-initiated state change, and therefore the call must be released
0600	File record congestion
0603	Program block has not been able to contact the program block acting as its partner program block
0606	No free conference devices available
0608	Setting of charging has failed
0609	Call has been cleared by order of the operation and maintenance system
060B	Call set-up has been interrupted because of overload in a unit or in the entire exchange
060C	The call cannot be continued because free call record isn’t found
060E	Unit restarted
0610	Echo Canceller failure
0620	IP User Plane is unreachable
0701	Register analysis has failed
0705	Module or V5 interface not available
0706	Call interrupted during register analysis
070A	Call refresher operation has cleared the call or call set-up
070B	Modem error
070D	An attempt to use the announcement service has failed
070E	Configuration error in the exchange
070F	Digital interface unit pool error

0710	No digit analysis created for the carrier access mode
0713	No ISUP route in the exchange that would meet the signaling requirements
0714	The route selection ended in congestion based on the attribute directed routing feature
0715	Requested facility was not available on the outgoing route
0716	Requested Bearer capability could not be fulfilled on the route
0718	Digital analysis in central memory resulted in congestion
0719	No resource available for call
071B	The requested channel is not available
0720	User plane resource is not available in CMN node
0721	Problem in User Plane Analysis
0722	User Plane Analysis resulted in the interruption of the call
0723	CTM call cannot be established
07FF	Is used as an initial value in all program blocks which set clear codes, before any services are made for the call

Table 9: Clear Codes - Internal Congestion [13]

External Congestion:

Number	**Name/Description**
0802	Length of the calling subscriber number exceeded
0804	All circuits of the external hunted route are occupied
0806	Identity of subscriber is not available
0807	Waiting time for MFC pause signal exceeded limit
0808	Waiting time for MFC backward signal exceeded limit
0809	The MFC character received from the outgoing circuit does not correspond to the choice of characters available for signaling
080A	The MFC character received from the incoming circuit does not correspond to the choice of characters available for signaling
080D	Outgoing circuit is out of order
080E	Incoming circuit is out of order
080F	Circuit congestion
0810	Service asked for is not supported in PLMN
0811	The NE is unable to perform the operation because some other network element is faulty
0812	Internal protocol error in the MAP
0813	Switching equipment congestion
0814	Circuit group congestion
0815	Accessed barred to the called subscriber
0816	“Send special information tone” message has been received from the network
0817	“Unallocated number” message has been received from the network
0818	“Line out of service or unused” message has been received from the network
0819	“Subscriber number changed” message has been received from the network

081A	Congestion in terminal exchange, which made call rerouting impossible
081B	HLR failure
081C	VLR failure
081D	Congestion in international call
081E	Controlled not ready
081F	Overload message has been received from the network
0820	The content of the network messages is erroneous
0821	The chosen transit network is erroneous or does not exist
0822	The recovery from an error situation has been initiated due to the timer in the network
0823	Erroneous call attempt from counter exchange
0824	PCM faulty
0825	The partner exchange or the NE does not recognize the seized circuit
0826	The network message has been discarded due to an unknown parameter in it
0827	Carrier identification code not allowed from incoming circuit
082A	MSS rejects resource reservation because RTP packet loss percentage limit is reached on an IP based route
082B	MSS rejects resource reservation because the maximum bandwidth is reached on an IP based route
082C	MSS rejects resource reservation because it is out of IP terminations on an IP based route
082D	MGW rejects the resource reservation because it is out IP terminations
082E	IP-PBX is not registered and outgoing calls fail
0830	Routing number of the subscriber has changed because the subscriber has moved to the network of another operator
0831	No valid response was received from number portability database
0832	Routing Error
0835	Formal error in SIP message
0836	NE has received a SIP method that is not supported
083A	VLR has rejected the call because of a zone restriction
083B	Called party answers a call already in disconnect phase, and only release message is expected
0840	Received message is referring to a non-existing call
0841	Session description is not acceptable
0843	MGW rejects the resource reservation with H.248 error code which indicates that MGW has congestion on
0844	Integrity checking in RNC has failed repeatedly
0845	An error has occurred in RANAP message encoding/decoding or the requested information is not available
0846	A transport layer error has occurred
0850	Service Centre congestion
0851	Traffic to congested destination point code restricted by signaling
0860	APM message was not reassembled
0861	APM message contains invalid addressing or an application identifier which is

	not supported
0870	H.248 protocol error
0871	Service change request command received
0872	Unknown user plane destination
0873	Error in codec negotiation
0874	Interconnection between two MGW is undefined
0875	MGW is unable to establish a bearer
0876	H.248 connection does not exist
0877	MGW load reduction
0880	Rerouting is not possible
0881	Unexpected action indicator
0882	Unrecognized information element
0883	Capability failure in MGW
0884	MGW sends a H.248 error code indicating a Context ID mismatch
0885	MGW internal failure
0886	MGW does not support a H.248 item
0887	MGW has problems handling the requested service
0888	Termination ID already exists within an active context
0889	Termination ID is in the 'Out-of-Service' state
088A	Termination ID mismatch in MGW
088B	MGW sends a H.248 error code that is not used
088C	Interworking problems noticed by the MGW
0900	No multifrequency forward signaling has been received from the incoming circuit
090D	Wait time for acknowledgement to seizure in outgoing circuit exceeded
0920	IP control plane unreachable
0A02	Invalid message from trunk circuit
0A03	Interworking failed
0A04	Trunk circuit protocol error
0A05	Message indicating release of the circuit has been received from the trunk circuit
0A07	Message indicating an unsuccessful call attempt has been received from the outgoing circuit
0A08	Destination point signaling out of order
0A09	"Address complete" message time-out
0A0B	No response to inquiry message from the network
0A0C	Desired route does not have a digital outgoing circuit
0A0D	No route to a specific transit network or partner exchange
0B10	V.110 frame synchronization failure

0B11	Modem communication error
0B12	RLP frame synchronization failure
0B13	Radio Interface failure
0B14	Handover failure
0B15	Ciphering algorithm is not supported
0B16	Remote equipment failure
0B17	Address incomplete
0B18	Service unavailable
0B19	Service incompatible
0B1A	Protocol error has occurred between MSC and BSC
0B1B	MSC has detected a message failure in the radio interface
0B1C	MS is unable to use the new channel to which the BSC is transferring the connection
0B1D	Call was cleared due to a O&M measure in the network
0B1E	Radio Resource is unavailable
0B1F	The allocation of the base station interface traffic channel (between MSC and BSC) was unsuccessful
0B20	Network address extension error
0B21	Data Terminal Equipment (DTE) does not function during an ISDN call
0B23	Dual seizure from bidirectional circuit
0B2A	Blocking received
0B2B	Parameter does not exist or is not implemented
0B2C	IN (Intelligent Network) application protocol error
0B2D	IN application response time out
0B2E	Maximum number of triggering events in a call has been reached
0B30	ASN.1 coding or decoding error
0B31	Selective call congestion has prevented call attempt
0B32	Call in the SCP or controlled by an internal IN application is cleared
0B33	Continuity check has been unsuccessful
0B38	IN service fallback code one
0B39	IN service fallback code two
0B3A	IN service fallback code three
0B3C	IN service fallback code four
0B3E	Call period time out
0B41	Bearer redirection to this node is failed
0B42	Bearer redirection to the next node is failed
0B43	Error in codec modification
0B44	Call ID is being used for another call
0B45	Offered or requested codec type is temporarily unavailable

0B46	Offered interface type is temporarily unavailable
0B47	Offered codec type or codec configuration is not supported
0B48	Offered interface type is not supported
0B49	No User Plane connection for CS call

Table 10: Clear Codes - External Congestion [13]

Subscriber Errors:

Number	**Name/Description**
0C01	Unknown dialing from subscriber signaling
0C02	Insufficient dialing from subscriber signaling
0C09	Service or facility activation restricted
0C0A	Service or facility usage restricted
0C0B	Inconsistency between the data on the calling and called subscriber
0C0C	Invocation of Calling Line Identification Restriction (CLIR) is not allowed
0C0D	Bearer capability not presently available
0C0E	Interaction error detected in the operation, caused by a mistake made by the subscriber
0C10	Carrier Access Code is not allowed
0C11	A data call is made to the operator number
0D00	Inconsistent or erroneous message between the exchange and the mobile station
0D01	Formal error in Subscriber signaling message
0D03	The service or facility requested by the subscriber has not been implemented
0D04	Signaling messages arrived in the wrong order in respect to the stage of the call
0D06	Call has been released because the MS with the supplementary Advice of Charge Service does not acknowledge the CAI information
0D07	MS has not responded with an Alerting or Connect message within the time limit at call set-up
0D08	The procedure has started the GSM recommendation 04.08 after the timer expiry
0D0D	The message received does not exist or it is not implemented
0D0E	Undefined Fax data rate
0D0F	Facility rejected
0D50	Invalid or inconsistent short message in subscriber signaling
0D51	Roaming is denied in the Location Area
0D52	Roaming is denied in the PLMN

Table 11: Clear Codes - Subscriber Errors [13]

Appendix B – MEGACO Error Codes

<u>MEGACO (H.248) error codes:</u>

(based on [42])

Number	**Name/Description**
400	Syntax error in message
401	Protocol error
402	Unauthorized
403	Syntax error in transaction request
406	Version not supported
410	Incorrect identifier
411	The Transaction refers to an unknown ContextID
412	No Context IDs available
413	Number of transactions in message exceeds maximum
421	Unknown action or illegal combination of actions
422	Syntax error in action
430	Unknown TerminationID
431	No TerminationID matched a wildcard
432	Out of TerminationIDs or No TerminationID available
433	TerminationID is already in a context
434	Max number of Terminations in a context exceeded
435	TerminationID is not in specified context
440	Unsupported or unknown package
441	Missing Remote or Local Descriptor
442	Syntax error in command
443	Unsupported or Unknown command
444	Unsupported or Unknown descriptor
445	Unsupported or Unknown property
446	Unsupported or Unknown parameter
447	Descriptor not legal in this command
448	Descriptor appears twice in a command
449	Unsupported or unknown parameter or property value
450	No such property in this package
451	No such event in this package
452	No such signal in this package
453	No such statistic in this package
454	No such parameter value in this package

455	Property illegal in this Descriptor
456	Property appears twice in this Descriptor
457	Missing parameter in signal or event
458	Unexpected Event/Request ID
459	Invalid combination of metering detection events
460	Unable to set statistic on stream
461	Unsupported or Unknown profile
471	Implied add for multiplex feature
472	Required information missing
473	Conflicting property values
474	Invalid SDP Syntax
475	Unable to pause the playout off the signal
476	Unable to adjust the data delivery speed of the signal
477	Unable to adjust the playback relative scale of the signal
500	Internal software Failure in MGW or MGC
501	Not Implemented
502	Not ready
503	Service Unavailable
504	Command Received from unauthorized entity
505	Transaction Request Received before a Service change reply has been received
506	Number of Transactions Pendings exceeded
510	Insufficient Resources
511	Temporarily Busy
512	Media Gateway unequipped to detect requested event
513	Media Gateway unequipped to generate requested signals
514	Media Gateway cannot send the specified announcement
515	Unsupported Media type
517	Unsupported or invalid mode
518	Event buffer full
519	Out of space to store digit map
520	Digit map undefined in MGW
521	Termination is “ServiceChangeing”
522	Functionality Requested in topology triple is not supported
526	Insufficient bandwidth
529	Internal hardware failure in MGW
530	Temporary network failure
531	Permanent network failure

532	Audited property, statistic, event or signal does not exist
533	Response exceeds maximum transport PDU size
534	Illegal write or read only property
540	Unexpected initial hook state
541	Unexpected Spare Bit state
542	Command is not allowed on this termination
543	MGC requested event detection timestamp not supported
581	Does not exist
600	Illegal syntax within an announcement specification
601	Variable type not supported
602	Variable value out of range
603	Category not supported
604	Selector type not supported
605	Selector value not supported
606	Unknown segment ID
607	Mismatch between play specification and provisioned data
608	Provisioning error
609	Invalid offset
610	No free segment IDs
611	Temporary segment not found
612	Segment in use
613	ISP port limit overrun
614	No modems available
615	Calling number unacceptable
616	Called number unacceptable
617	Reserved for H.248.9 return code
618	Reserved for H.248.9 return code
622	Reserved for H.248.9 return code
623	Reserved for H.248.9 return code
624	Reserved for H.248.9 return code
625	Reserved for H.248.9 return code
626	Reserved for H.248.9 return code
627	Reserved for H.248.9 return code
628	Reserved for H.248.9 return code
629	Reserved for H.248.9 return code

Table 12: MEGACO error codes [42]

Appendix C – SGSN Error Codes

SGSN error codes are grouped as follows (According to [43]):

- MS initiated attach (GPRS or combined) reject by network
- MS initiated combined attach accepted GPRS services only (CS-side fails)
- MS initiated Routing Area Update rejected by network
- MS initiated combined Routing Area Update accepted for GPRS services only
- MS initiated PDP context activation rejected by the network
- MS initiated PDP context modification rejected by the network
- Network requested PDP context deactivation
- MS initiated service request rejected by the network

Appendix D – RTT Report fields

RTT Report most relevant fields (based on [12]):

Signalling_Complete_Time

- If this field is empty, it means that call signaling phase is not completed and the setup of the call has failed.

Data type in IDS	BCDTIME
MSC Version	M13, M14, M15, M16, M16.1, M16.2
Explanation	Time part of the signaling complete time. This is the time when the signaling of the call has been completed. Signaling_Complete_Time is present in the report if the signaling has been successfully completed.
Possible values	
Field exists in the database	Yes, the field Signaling_Complete_Time contains both the date and time as SQL TIMESTAMP data type.

Table 13: Signaling Complete Time field [12]

Charging_End_Time

Data type in IDS	BCDTIME
MSC Version	M13, M14, M15, M16, M16.1, M16.2
Explanation	The time part of the call end time. This is not actually charging end time because it is only available in CDRs. Charging_End_Time is present if B has answered the call. In this case, the call duration is Charging_End_Time minus B_Answered_Time.

Possible values	
Field exists in the database	Yes, field Charging_End_Time contains date and time (as SQL TIMESTAMP data type)

Table 14: Charging End Time field [12]

B_Answered_Date

Data type in IDS	BCDDATE
MSC Version	M13, M14, M15, M16, M16.1, M16.2
Explanation	The date part of the time when the B subscriber answered the call. If the call is not answered, this field contains an empty value.
Possible values	
Field exists in the database	Yes, the field B_Answered_Date contains both the date and time (as SQL TIMESTAMP data type)

Table 15: B Answered Date field [12]